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AGRICULTURAL ENGINEERING

The Journal of Engineering as Applied to Agriculture

Vol. 8 APRIL, 1927 No. 4

# Tractor Lug Studies on Sandy Soil*

## II - Field Studies

By John W. Randolph[1]

EDITOR'S NOTE: It is especially noteworthy that this paper, which is the second contribution from Prof. Randolph reporting the tractor lug studies on sandy soil at the Alabama Agricultural Experiment Station, is a progress report of an Adams Fund project in mechanical farm equipment. In fact, it is the only Adams Fund project of its kind at any of the agricultural experiment stations.

THIS paper presents the results of further studies of the factors affecting the traction of wheel tractors. The results of the laboratory studies previously reported[2] may be briefly summarized as follows:

1. The distribution of the weight of a tractor wheel influences the resistance of soil to shear by a lug, and the resistance depends upon the arch action of the components of force acting through the soil. The greatest efficiency is obtained when a weight is placed upon the wheel sufficient to force the lug into the soil and hold the rim in contact with it. With a series of increasing loads upon the wheel the output or drawbar pull increases to a maximum and then gradually diminishes.

2. The output or drawbar pull varies directly with the depth of the lugs.

3. Spade lugs (made by removing sections of angle lugs) are superior to solid lugs in sand which has high arch action characteristics.

In the same study the following results were obtained which were not reported:

1. The shape of the lug after entering the soil has little effect upon its output.

2. In the process of entering the soil sharp lugs encounter the least resistance and blunt lugs give the best wheel support in loose sand.

*Paper presented at the meeting of the Farm Power and Machinery Division of the American Society of Agricultural Engineers, at Chicago, December, 1926.

[1]Assistant agricultural engineer, Alabama Agricultural Experiment State. Mem. A.S.A.E.

[2]AGRICULTURAL ENGINEERING, Vol. 7, No. 5 (May, 1926), page 178. Also A.S.A.E. Transactions, Vol. 20 (1926), page 67.

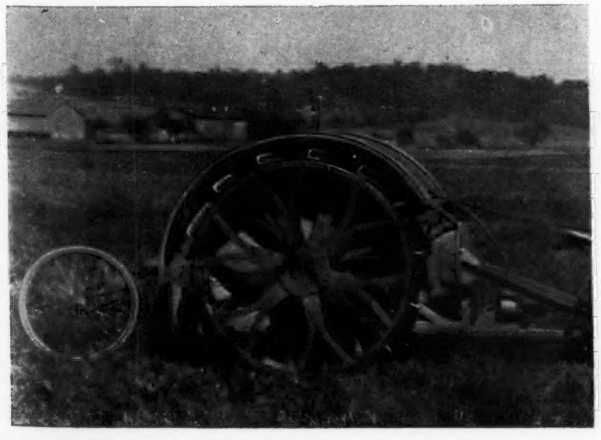


Fig. 1. The testing equipment used in the Alabama tractor lug studies on sandy soil

### FIELD TESTS

The primary object of the work reported in this paper was to test the laboratory findings under actual field conditions, and thus to determine their practical value. The field selected for this study was a comparatively level area of Norfolk sand. The soil was plowed 6 to 7 inches deep before each test to make the conditions uniformly unfavorable for traction. The soil in the field was similar to the loose sand used in the laboratory study.

In making these tests two standard tractors were used, the 10-20 McCormick-Deering and the Fordson. Each tractor was operated as recommended by the manufacturer. A speedometer was attached to the motor which was kept at its rated speed by hand control of the throttle.

A General Motors Research Corporation dynamometer car served for the controlable drawbar load. The drawbar load, time, and distance were measured and recorded with a Hyatt recording dynamometer, as shown in Fig. 1. The percentage of slip was determined by comparing the distance the tractor traveled per revolution of the drivewheels without a drawbar load with the distance the tractor traveled with a drawbar load. The revolutions of the wheels were recorded by a revolution counter.

With the lug equipment, as shown in Table I, thirty-four combinations of lugs and nine different distributions of weight on the drivewheel were tested. As similar equipment was not available for each tractor the results cannot be considered to give a comparison of the two makes of tractors. With each set of lugs the tractor was given four loads in both low and second gear; (a) A drawbar load sufficient to cause a slight slip of the tractor drivewheels but which permitted the motor to maintain its rated speed; (b) a load which produced considerable digging in of the drivewheels, but which caused no great loss in forward travel; (c) a load which caused the wheels to slip excessively but permitted some forward travel; and (d) a load that either stalled the motor or caused the wheels to dig themselves into the soil to a point where forward travel became zero.

TABLE I. Tractor, Wheel, and Lug Specifications

| Lug No. | Type of lug | Lugs per wheel | Height of lug, inches | Width of lug, inches | Total volume of lug, cu. in. |
|---|---|---|---|---|---|
| A. | McCormick-Deering 10-20 tractor (2590 pounds upon rear wheel, 41 inches in diameter) | | | | |
| 1. | Angle* | 16 | 3.92 | 13.85 | |
| 2. | Angle | 16 | 4.06 | 18.75 | |
| 3. | Angle | 16 | 2.12 | 14.00 | |
| 4. | Angle | 16 | 2.12 | 19.50 | |
| 5. | Cone | 32 | 3.00 | 2.50 | 4.9 |
| 6. | Spade | 32 | 4.00 | 3.50 | 18.6 |
| 7. | Spade | 32 | 5.00 | 3.50 | 31.7 |
| B. | Fordson tractor (1980 pounds upon rear wheels, 42 inches in diameter) | | | | |
| 8. | Angle | 14 | 2.90 | 15.00 | |
| 9. | Ford angle spade** | 14 | 6.00 | 14.50 | |

*All angle lugs attached in standard position.

**Lug made of one-half-inch flat iron, 14.5 by 6 inches bolted to regular lug. By removing small sections the cutting edge was formed into three spade lugs, 2½ by 3 inches with ½-inch taper of lug sides.

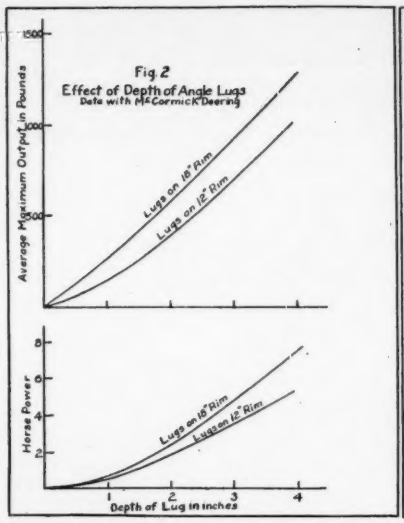
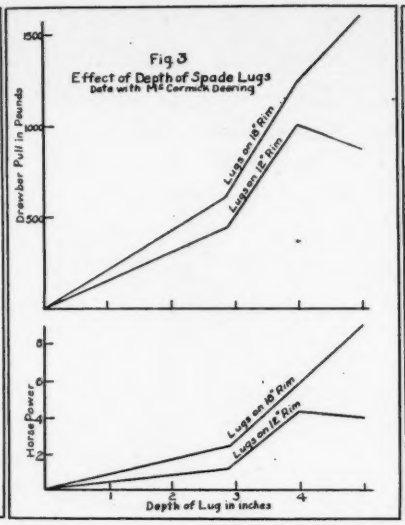


Fig 2
Effect of Depth of Angle Lugs
Data with McCormick Deering
Average Maximum Output in Pounds
Lugs on 18" Rim
Lugs on 12" Rim
Horse Power
Depth of Lug in inches



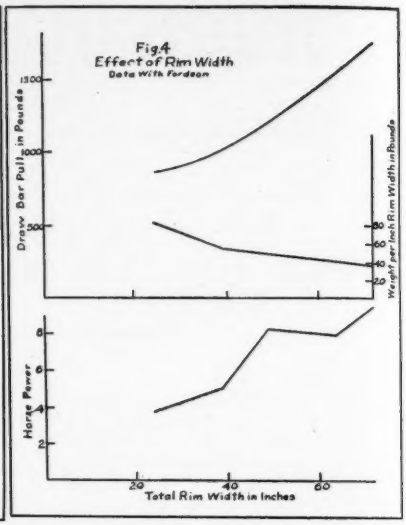



Fig 4
Effect of Rim Width
Data with Fordson
Draw Bar Pull in Pounds
Weight per Inch Rim Width in Pounds
Horse Power
Total Rim Width in Inches

## RESULTS

The field tests covered the effect of the following factors: (a) Depth of angle lugs, (b) depth of spade lugs, (c) distribution of weight on drivewheels or width of rim, (d) lug spacing, and (e) speed. It will be noted that the first four factors were studied in the laboratory tests.

**Depth of Angle Lugs.** Table II gives the results obtained with several combinations of angle lugs. The McCormick-Deering tractor, with the standard 12-inch rim without lugs, was unable to pull the dynamometer but was able to produce a static force of 450 pounds. Lug 3, which was 2.12 inches deep, on the standard rim permitted the development of 476 pounds pull, 2.1 horsepower and a static force of 690 pounds. Lug 1, 3.94 inches deep, on the standard rim (At the time of this study this was the lug and wheel equipment sold for sandy soil conditions.) obtained a fair hold upon the soil for light loads. For heavier loads the wheels would dig in rapidly, because of inadequate bearing surface. The tractor with standard equipment developed 1056 pounds pull and 5.36 horsepower. This was 53 per cent of the tractor's rated power. Lug 2, 4.06 inches deep, gave the following increase over Lug 4, 2.12 inches deep: On the 12-inch rim, 191 per cent in horsepower and 94 per cent in drawbar pull; and on the 18-inch rim, 181 per cent in horsepower and 94 per cent in drawbar pull. Lug 2 on the 18-inch rim gave 77 per cent of the rated power of the tractor. Fig. 2 represents graphically the above results for drawbar pull and horsepower. One will note that the drawbar pull varied directly with the depth of lug as was found in the laboratory. The static drawbar pulls obtained in the laboratory results were found to hold in the field.

A special angle lug attachment (No. 9) was used on the Fordson which increased the standard lug to 6 inches in depth. The cutting edge of this lug was made in the form of a triple spade lug. This special lug produced 70 per cent greater drawbar pull and horsepower than standard equipment.

**Spade Lugs.** Two sets of spade lugs and one set of spud lugs were tested on the McCormick-Deering tractor. Table III gives the results obtained with these lugs when attached in the standard position on the rim. When drawbar pull and horsepower are plotted against depth, the result is a broken line rather than a straight line due to the fact that the shape and volume of the lugs varied greatly. The effect of shape and volume was not so great where an 18-inch rim was used, the graph being nearly a straight line. A further explanation of the variation of these curves is given under "Lug Spacing." Lug 7 on the 18-inch rim gave the best support to the weight of the tractor and the greatest traction of any lug combination tested on the McCormick-Deering

**TABLE II. Relation of Depth of Angle Lugs to Traction**

| Lug No. | Depth, inches | Gear | Maximum horsepower* D/t | A.P. | H.P. | Ef. | Maximum average pull** D/t | A.P. | H.P. | Ef. | Maximum*** pull |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | McCormick-Deering Tractor**** | | | | | | | | |
| 0 | 0.00 | | | | | | | | | | 450 |
| 3 | 2.12 | L | 107 | 476 | 1.54 | 54 | 107 | 476 | 1.54 | 54 | 690 |
| | | S | 148 | 467 | 2.10 | 58 | 148 | 467 | 2.10 | 58 | 690 |
| 1 | 3.94 | L | 147 | 1056 | 4.70 | 58 | 147 | 1056 | 4.71 | 58 | 1800 |
| | | S | 193 | 916 | 5.36 | 62 | 135 | 1030 | 4.22 | 53 | 1420 |
| 4 | 2.12 | L | 134 | 548 | 2.22 | 81 | 114 | 575 | 1.97 | 50 | 780 |
| | | S | 156 | 500 | 2.36 | 81 | 124 | 561 | 2.11 | 61 | 740 |
| 2 | 4.06 | L | 185 | 987 | 5.55 | 75 | 139 | 1119 | 4.72 | 57 | 2250 |
| | | S | 243 | 934 | 6.88 | 89 | 243 | 934 | 6.89 | 89 | 2150 |
| | | | Lugs on eighteen-inch rim | | | | | | | | |
| 0 | 0.00 | | | | | | | | | | 470 |
| 4 | 2.12 | L | 126 | 630 | 2.40 | 86 | 107 | 675 | 2.19 | 57 | 1000 |
| | | S | 150 | 603 | 2.74 | 61 | 134 | 607 | 2.46 | 55 | 950 |
| 2 | 4.06 | L | 148 | 1210 | 5.43 | 58 | 125 | 1310 | 4.95 | 83 | 3000 |
| | | S | 248 | 1034 | 7.76 | 79 | 175 | 1199 | 6.38 | 65 | 1580 |
| | | | Fordson Tractor<br>Regular wheels and standard lugs | | | | | | | | |
| 8 | 2.90 | L | 136 | 642 | 2.64 | 83 | 93 | 859 | 2.42 | 55 | 1280 |
| | | S | 186 | 664 | 3.74 | 73 | 148 | 701 | 3.13 | 62 | 1200 |
| | | | Lugs on regular wheels | | | | | | | | |
| 9 | 6.00 | L | 191 | 980 | 5.67 | 71 | 120 | 1463 | 5.32 | 58 | 2100 |
| | | S | 355 | 591 | 6.36 | 90 | 217 | 917 | 6.02 | 45 | 1400 |

D/t = average speed in feet per minute
A.P. = average pull in pounds
H.P. = horsepower
Ef. = distance traveled per revolution of drivewheels under test compared to a similar measurement without drawbar load upon the same soil condition
*Data used in this condition was one giving highest horsepower of the first three conditions of drawbar load
**Data from the third condition of drawbar load
***Fourth condition of load
****Rim widths given for one wheel

**TABLE III. Relation of Depth of Spade Lugs to Traction***
McCormick-Deering Tractor

| Lug No. | Depth, inches | Gear | Maximum horsepower D/t | A.P. | H.P. | Ef. | Maximum average pull D/t | A.P. | H.P. | Ef. | Maximum pull |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Spade lugs on twelve-inch rim | | | | | | | | |
| 5 | 2.87 | L | 100 | 410 | 1.24 | 55 | 71 | 450 | 0.97 | 42 | 500 |
| | | S | 97 | 420 | 1.24 | 53 | 80 | 450 | 1.06 | 47 | 580 |
| 6 | 4.00 | L | 181 | 773 | 4.24 | 80 | 102 | 1030 | 3.18 | 64 | 1500 |
| | | S | 217 | 671 | 4.41 | 91 | 122 | 981 | 3.60 | 62 | 1280 |
| 7 | 5.00 | L | 139 | 885 | 3.72 | 82 | 114 | 860 | 2.97 | 82 | 1057 |
| | | S | 172 | 775 | 4.04 | 94 | 139 | 885 | 3.82 | 82 | 980 |
| | | | Spade lugs on eighteen-inch rim | | | | | | | | |
| 5 | 2.87 | L | 124 | 605 | 2.29 | 85 | 101 | 625 | 1.91 | 54 | 900 |
| | | S | 154 | 512 | 2.39 | 62 | 126 | 570 | 2.17 | 20 | 840 |
| 6 | 4.00 | L | 148 | 1201 | 5.39 | 68 | 117 | 1254 | 4.49 | 49 | 1800 |
| | | S | 232 | 839 | 5.90 | 68 | 130 | 1060 | 4.20 | 73 | 1500 |
| 7 | 5.00 | L | 151 | 1363 | 6.24 | 40 | 74 | 1630 | 3.75 | 37 | 3000 |
| | | S | 393 | 769 | 9.16 | 82 | 282 | 880 | 7.51 | 92 | 1950 |

*Lugs in standard attachment to rim

**TABLE IV. Relation of Width of Rim to Traction**
Fordson Tractor

| Wheel equipment | Total rim width, in. | Gear | Maximum horsepower D/t | A.P. | H.P. | Ef. | Maximum average pull D/t | A.P. | H.P. | Ef. | Maximum pull |
|---|---|---|---|---|---|---|---|---|---|---|---|
| R* | 23.75 | L | 136 | 642 | 2.64 | 83 | 93 | 859 | 2.42 | 55 | 1280 |
| | | S | 186 | 664 | 3.75 | 73 | 148 | 701 | 3.13 | 62 | 1200 |
| R + E** | 39.00 | L | 152 | 607 | 3.09 | 86 | 81 | 1025 | 2.49 | 48 | 1820 |
| | | S | 258 | 666 | 5.21 | 83 | 95 | 1011 | 2.94 | 46 | 1508 |
| Two R | 48.50 | L | 162 | 822 | 4.05 | 90 | 97 | 1201 | 3.53 | 51 | 2200 |
| | | S | 339 | 809 | 8.31 | 91 | 163 | 1072 | 5.40 | 83 | 1800 |
| Two R + E | 63.75 | L | 128 | 1142 | 4.44 | 73 | 73 | 1519 | 3.38 | 43 | 2700 |
| | | S | 253 | 1038 | 7.96 | 82 | 253 | 1038 | 7.96 | 82 | 1600 |
| Three R | 73.25 | L | 169 | 1264 | 6.49 | 82 | 63 | 1780 | 3.42 | 37 | 3000*** |
| | | S | 270 | 1160 | 9.52 | 91 | 180 | 1176 | | 28 | 1550 |

*Regular wheel
**Fordson extension rim
***An extension rim clamp was used in rim attachment. This increased the total rim width one inch for each additional rim

tractor. While these results show an increase of 54 per cent in drawbar pull and 71 per cent in horsepower over standard equipment, they do not represent the possible maximum accomplishment of the tractor. Fig. 3 expresses these results graphically.

**Weight Distribution or Rim Width.** With three sets of regular wheels and one set of regular extension rims, five combinations of rim widths were tested on the Fordson tractor as shown in Table IV and Fig. 4. The regular wheel permitted the tractor to sink into the soil 3 to 4 inches without a load. With a rim width a little wider than three times the standard rim width the wheel sank into the soil about one-half inch. The resistance of the soil to the entrance of the lugs was about equal to the weight on the wheel when using triple wheel width. The results show that as the rim width was varied between the above extremes, the widest rim gave an increase of 100 per cent drawbar pull and 150 per cent horsepower. The curve of the results of the 6-inch extension rim does not coincide with the curve obtained for the regular wheels. The variation is accounted for by the fact that the extension rim lugs and the bearing per inch of rim width were not in proper proportion to the same factors on the regular wheel. On the basis of weight distribution, the differences in drawbar pull are fairly uniform for the five widths of rim. Weight distribution is also discussed under "Lug Spacing."

**Lug Spacing.** The following findings in the laboratory study explain the results obtained by the combinations of lugs, lug spacing, and rim widths used in the field: (a) Rolling resistance varies directly with the depth of lug; (b) if the lug enters the soil, the vertical component of the resistance of the soil to the entrance of a lug must be less than the weight on the wheel; (c) the weight on the rim increases the arch action of the soil; (d) with a weight greater than the bearing power of the soil, the wheel sinks in, and its rolling resistance is increased by the equivalent grade formed by the soil in front of the wheel.

With one exception all lugs were tested using the standard distances on the circumference of the wheel. Variations in lug spacing and arrangement were tested. Lug 5, a cone or spud lug 2.8 inches deep, did not give traction equal to that given by angle Lugs 3 and 4 which had less depth. This lug was so small that it cut through the soil and did not take advantage of its arch forming properties. When Lug 6, 3 inches wide and 4 inches deep, was placed on one side of the 12-inch rim, the arch action was such that the soil was sheared almost to the opposite side of the rim. (Note Table V for traction results.) When two lugs were placed on the edge of the 18-inch rim side by side the arch action of the two lugs overlapped. A staggered setting of the lugs gave the greatest traction.

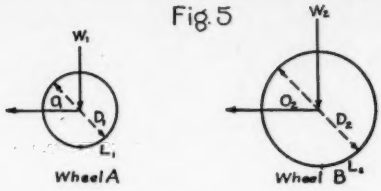
Lug 7 in entering the soil displaced 70 per cent more soil than Lug 6. The results show that Lug 7 gave less traction on the 12-inch rim and more traction on the 18-inch rim than Lug 6. In the first case, the lugs were so closely spaced that they supported the tractor before the rim made a good soil contact, This was due to the fact that the wedging action of the lugs compressed the soil thereby increasing its bearing value. With a low pressure on the rim the soil had a low resistance to shear, and its shear angle was nearly the normal shear angle of unconfined soil, that is 45 degrees. On the 18-inch rim the lugs were spaced farther apart, which permitted them to sink into the soil. This allowed the rim to slightly confine and compress the soil. The shear angle was vectored downward giving greater traction results. Removing every other lug in Set 2 on the 18-inch rim reduced the maximum horsepower 56 per cent and the drawbar pull 42 per cent as the soil arches did not meet and the full possible shear value was not approached.

**Speed.** With the same number of revolutions of the drive-

**TABLE V. Effect of Lug Arrangement**
McCormick-Deering Tractor

| Lug arrangement | Width of rim, in. | Gear | Maximum horsepower D/t | A.P. | H.P. | Ef. | Maximum average pull D/t | A.P. | H.P. | Ef. | Maximum pull |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 Paired | 12 | L | 181 | 773 | 4.24 | 80 | 102 | 1031 | 3.18 | 62 | 1280 |
| | | S | 217 | 671 | 4.45 | 91 | 122 | 1030 | 3.81 | 64 | 1500 |
| 6 16 lugs on inside | 12 | L | 157 | 922 | 4.38 | 81 | 157 | 922 | 4.38 | 81 | 1350 |
| | | S | 154 | 1016 | 4.74 | 68 | 154 | 1016 | 4.74 | 68 | 1250 |
| 6 16 lugs staggered | 12 | L | 141 | 741 | 3.17 | 78 | 107 | 940 | 3.05 | 67 | 1020 |
| | | S | 256 | 551 | 4.25 | 87 | 139 | 870 | 3.66 | 77 | 1000 |
| 6 Paired 32 lugs on regular rim | 18 | L | 146 | 957 | 4.24 | 68 | 123 | 1036 | 3.88 | 64 | 1420 |
| | | S | 188 | 896 | 5.11 | 73 | 140 | 1056 | 4.48 | 60 | 1430 |
| 6 Paired 32 lugs | 18 | L | 148 | 1201 | 5.37 | 68 | 148 | 1201 | 5.37 | 68 | 1550 |
| | | S | 162 | 973 | 4.77 | 82 | 162 | 973 | 4.77 | 82 | 1300 |
| 6 Staggered | 18 | L | 117 | 1254 | 4.49 | 49 | 117 | 1254 | 4.49 | 49 | 1570 |
| | | S | 232 | 839 | 5.89 | 68 | 166 | 925 | 4.06 | 48 | 1200 |
| 2 Standard | 18 | L | 148 | 1210 | 5.45 | 58 | 125 | 1310 | 4.95 | 83 | 3000 |
| | | S | 248 | 1034 | 7.78 | 59 | 175 | 1199 | 6.38 | 65 | 1580 |
| 2 Every other lug removed | 18 | L | 113 | 987 | 3.38 | 46 | 113 | 987 | 3.88 | 46 | 1256 |
| | | S | 144 | 788 | 3.44 | 52 | 144 | 788 | 3.44 | 52 | 1200 |

Fig. 5




L = Depth of Angle Lug
D = Diameter of Wheel
W = Weight per inch Rim Width
O = Output or Drawbar Pull
F = Rim Width

$$\text{If} \begin{cases} \frac{L_2}{L_1} = \frac{D_2}{D_1} \\ \frac{W_2}{W_1} = \frac{D_2}{D_1} \end{cases}$$

$$\text{Then} \quad \frac{O_2}{W_2} \text{ of Wheel } A = \frac{O_1}{W_1} \text{ of Wheel } B$$

$$\frac{O_2}{O_1} = \frac{\sqrt{L_2} + D_2 + W_2}{\sqrt{L_1} + D_1 + W_1}$$

$$\text{Or} \quad \Sigma O_2 = \frac{\Sigma O_1}{F_1} \cdot F_2 \cdot \frac{\sqrt{L_2} + D_2 + W_2}{\sqrt{L_1} + D_1 + W_1}$$

wheels, the rate of travel depends upon the ability of the lug to obtain traction, disregarding the small equivalent increase in the wheel diameter due to the lugs. The speed curve is parallel to that of the drawbar pull. The speed varied with the lug depth and inversely with the weight per inch of rim width.

**Field and Laboratory Data Compared.** A comparison of the field data with the laboratory data showed that, if two traction wheels are so loaded that the weights per inch of rim width are in direct proportion to their diameters and if the two wheels are fitted with angle lugs of depths proportional to the squares of their diameters, then each wheel can produce a similar output percentage of weight imposed. From these conditions a general formula can be derived as shown in Fig. 5.

Fig. 6 gives laboratory results for several different depths of lugs with four different weights on the wheel. Using the laboratory results and the weights and lug depths comparable to the Fordson wheel a curve, as shown in Fig. 7, gives the relation of the output-weight ratio as the ordinate and the weight on the wheel as the abscissa. This curve is practically identical with a similar curve of the field data. Similar curves were true for all conditions and combinations of lugs tested. Table VI compares the calculated results from the

**TABLE VI. Laboratory and Field Data of Fordson Compared**

| Total rim width, inches | Weight on rear wheels | Weight per inch rim width | Output weight ratio | Drawbar pull, lbs. | |
|---|---|---|---|---|---|
| | | | | Calculated | Actual |
| 23.75 | 1980* | 83.3 | 0.420 | 831 | 859 |
| 39.00 | 2150 | 55.1 | 0.503 | 1081 | 1025 |
| 48.50 | 2410 | 49.7 | 0.528 | 1272 | 1201 |
| 63.75 | 2580 | 40.5 | 0.585 | 1509 | 1519 |
| 73.25 | 2840 | 38.8 | 0.600 | 1704 | 1780 |

*Weight of tractor on rear wheel calculated from tractor literature and weight of equipment.

**TABLE VII. Laboratory Data Interpreted Into Field Data**

| Total rim width, inches | Weight on rear wheels | Drawbar pull | | |
|---|---|---|---|---|
| | | Three-inch lugs | Five-inch lugs | Seven-inch lugs |
| 24 | 3000 | 810 | 1275 | 1590 |
| 36 | 3400 | 1290 | 1845 | 2380 |
| 48 | 3800 | 1635 | 2360 | 3025 |
| 60 | 4200 | 1890 | 2755 | 3595 |
| 72 | 4800 | 2160 | 3185 | 4140 |

above curve with actual field results obtained with the Fordson tractor.

The following is an example of how to make a practical application of the data in Fig. 6. Assume that a 12-20 tractor is to be so equipped that it can develop the following drawbar pull in loose sand: 1800 pounds in second gear and 3600 pounds in low gear. To obtain these results in sand the standard wheel equipment can be varied in two ways: (1) By increasing the rim width; (2) by the use of lugs of greater depth. Fig. 8 gives a curve similar to that in Fig. 7 with three depths of lugs. Table VII gives the calculated drawbar pull with the above tractor for several different widths of rims, allowing a small increase in weight with each rim extension. From the preceding data the following combinations of wheel and lug equipment should develop the above desired maximum drawbar pull:

A. 1800 pounds drawbar pull
3-in. lug on 52 in. total rim width
5-in. lug on 36 in. total rim width
7-in. lug on 27 in. total rim width

B. 3600 pounds drawbar pull
7-in. lug on 54 in. total rim width

## SUMMARY

1. The laboratory findings previously reported were verified in the field

2. The output-weight ratios were similar for the test wheel in the laboratory and for tractors in the field

(a) Weight per inch of rim width is proportional to the diameter of the wheel

(b) Depth of angle lugs is proportional to the square of the wheels diameter

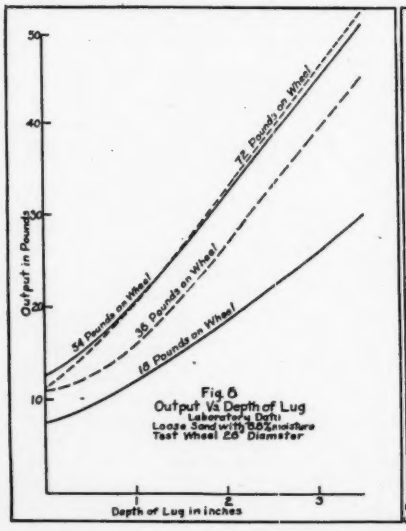



Fig. 6
Output Vs Depth of Lug
Laboratory Data
Loose Sand with 5.5% Moisture
Test Wheel 28" Diameter

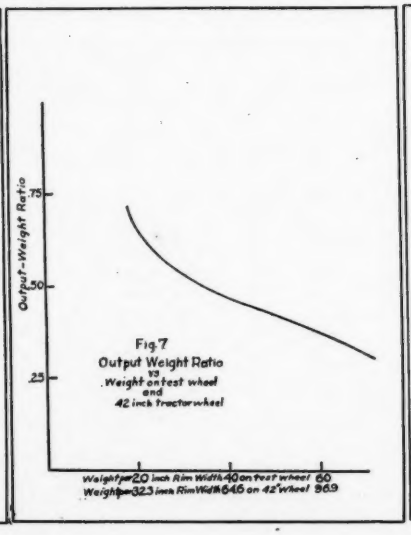

Output-Weight Ratio
.75
.50
.25
Weight per 20 inch Rim Width 40 on test wheel 60
Weight per 32.3 inch Rim Width 64.6 on 42" wheel 96.9

Fig. 7
Output Weight Ratio
vs
Weight on test wheel
and
42 inch tractor wheel

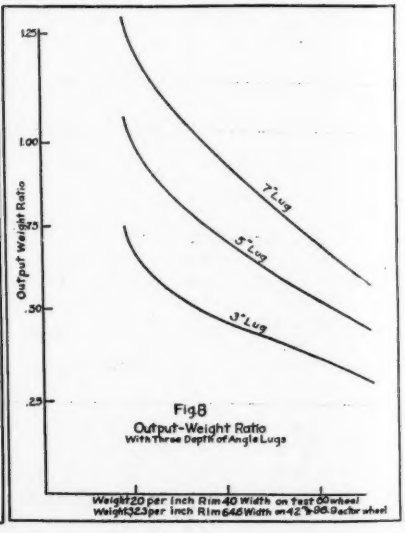



Fig. 8
Output-Weight Ratio
With Three Depth of Angle Lugs

3. Traction is influenced by the weight per inch of rim width, depending upon the lugs and the rim taking full benefit of the arch action of the soil

4. Drawbar pull, horsepower, and rolling resistance vary directly with the depth of lug

5. The tractors tested were found to require a wider rim or deeper lug than standard equipment to obtain their rated power in loose sand

6. Spade lugs are superior to angle lugs in loose sand when the wheel carries a relatively high unit weight. Easy penetrating lugs are superior on wheels that carry light loads

7. The proper spacings of lugs depends upon the arch action value of the soil, the laws of which have not as yet been determined

8. The relation of traction between two wheels can be expressed by the following formula, provided the weight per inch of rim width and the depth of lugs are in the ratios given in (2) above:

$$O_2 = O_1 \frac{\sqrt{L_2} + D_2 + W_2}{\sqrt{L_1} + D_1 + W_1}$$

in which O is output, D is wheel diameter, L is depth of lug, and W is weight per inch of rim width.

AUTHOR'S NOTE: The author wishes to express his appreciation to M. L. Nichols and R. W. Trullinger for their help and suggestions; to the International Harvester Company and the J. I. Case Threshing Machine Company for the use of tractors and lug equipment; to the Ford dealers of Alabama for the gift of a Fordson tractor, and to the Hyatt Roller Bearing Company for the loan of a Hyatt recording traction dynamometer.

# A Bureau or a Division of Agricultural Engineering?

By Arnold P. Yerkes[1]

THE members of the agricultural engineering profession are generally agreed as to the desirability of converting the present Division of Agricultural Engineering of the Bureau of Public Roads, U. S. Department of Agriculture, into a "bureau of agricultural engineering." It remains, however, to convince certain members of Congress of the desirability of this change, and in order to do this it will be necessary to show them very definitely how a bureau of agricultural engineering could accomplish better results than a mere division of a bureau.

Congress has already shown that it believes that a certain amount of work should be carried on in agricultural engineering, by appropriating money for the past several years for the maintenance of the present Division of Agricultural Engineering. It is obvious, therefore, that what we need to do is not to convince them of the desirability of carrying on such work, but to prove to them that there are good reasons why this work will result in greater benefits to American agriculture if conducted by a bureau than if conducted under a division of a bureau.

Inasmuch as the personnel of a new bureau, if created, would undoubtedly be practically identical with the present personnel of the Division of Agricultural Engineering, it may seem as though it would be difficult to furnish adequate arguments of this kind.

The creation of a Bureau of Agricultural Engineering would give considerable additional prestige to this branch of agricultural scienee, which is much to be desired from the standpoint of the profession, but this would probably not be a very weighty argument with the members of Congress who will largely decide this matter.

It is a well-known fact throughout the profession that during the past few years there have been a number of commissions, committees, and other similar bodies appointed to investigate and report upon certain phases of American agriculture, on which was a representative of practically every branch of agricultural science, with the exception of agricultural engineering. It is also well known that, as a consequence, several important reports and recommendations have been made in which agricultural engineering phases of the problems were entirely overlooked, to the detriment of the organization's work and to American agriculture in general.

The omission of agricultural engineering representatives from these bodies can be traced largely to the fact that no Bureau of Agricultural Engineering existed in the Department of Agriculture.

Besides the bodies just referred to, there are frequently conferences held in Washington, either inter-department or intra-department, where it is highly desirable that an agricultural engineer should be present, but where no such representative is included because the members of the conference are made up of single representatives from each bureau of the department, or departments, interested.

It might be argued that, if a representative of the Bureau of Public Roads were in attendance at such conferences, the agricultural engineering profession was represented by him, but this is not true, in fact, for the reason that the Division of Agricultural Engineering has no close connection with the principal work and activities of the Bureau of Public Roads, of which it is a part. In this respect is is quite different from most divisions of bureaus.

It is obvious that a representative of the Bureau of Public Roads would generally be selected from the part of the personnel engaged in the principal work of the bureau, namely, creation and maintenance of good roads. Regardless of how high-grade a road engineer such a representative might be, it is impossible for him to be equally familiar with the many phases of agricultural engineering. Hence, he could not possibly recognize the various ways in which agricultural engineering might have an influence upon the subjects under discussion.

It goes without saying that there are many conferences between the Secretary of Agriculture and his chiefs of bureaus, and there is no doubt but that agricultural engineering is involved in many of them and should have a representative to speak for it, but in spite of the very friendly and sympathetic attitude of the present chief of the Bureau of Public Roads toward the Division of Agricultural Engineering, and the profession in general, and nothwithstanding his deservedly high rank in road engineering, he could not be expected to recognize the agricultural engineering aspects of the problems discussed.

From the standpoint of the amount of money invested by American farmers in equipment falling within the scope of the agricultural engineer and their annual expenditures in this field, as compared with the amounts of money invested and expended along other lines, a Bureau of Agricultural Engineering is more than justified. The fact that such a bureau has not already been created in the Department of Agriculture undoubtedly accounts to a considerable extent for the failure of our state colleges as a whole, to appropriate adequate funds for carrying on sadly needed research and extension work in agricultural engineering, which would have been of immense financial benefit to American agriculture if carried on.

Now that the present Secretary of Agriculture has inaugurated activities in connection with agricultural engineering, designed to bring about greater activities on the part of the state colleges and experiment stations in this work, it is naturally more desirable than ever before that the agricultural engineering work in the Department be given the recognition it deserves, by adding the dignity and prestige to this work which would be accomplished through the creation of a Bureau of Agricultural Engineering.

It should hardly be necessary to point out that the chief of a bureau has considerably greater authority in undertaking many kinds of work and especially in cooperating with other organizations than has the chief of a division. The agricultural engineering profession has nothing but praise and thanks for the treatment the Division of Agricultural Engineering has received at the hands of the present chief of the Bureau of Public Roads, but if a separate bureau could be created to deal with agricultural engineering exclusively, it is safe to say that the results accomplished would be far greater than can ever be expected from a division of another bureau.

[1]Editor, "Tractor Farming," International Harvester Company. Mem. A.S.A.E.

# Corn Borer Fight Being Waged With Machinery

MACHINERY will be the principal weapon used in fighting the ten-million-dollar corn borer war recently declared by the federal government. Entomologists generally agree that it can best be killed by mechanical means. Government orders for large amounts of equipment with which to fight the new war are being given precedence over other orders by the machinery manufacturers, as in the days of the World War, in order that the government may effectively combat this new pest. Already a trainload of tractors, trucks, stubble pulverizers and other pieces of equipment are on their way to the battle fronts in New York, Pennsylvania, Ohio, Michigan and Indiana. There, under the general direction of the U.S.D.A. Bureau of Entomology, they will be the principal means of combating the borer in the 60,000,000 acres which are infested.

The stubble pulverizer is a new machine, especially designed to combat the borer. Corn stubble is known to be a favorite hibernating place of the borers. The pulverizer is provided with two sets of vertical blades set near the ground. In operation, these blades rotate at a high speed by power received, through the power take-off shaft, from the tractor which pulls the pulverizer. The rapidly revolving blades slice the stubble into small pieces and incidentally cut and kill any corn borers in the stubble. Traveling at a rate of three miles an hour over two rows of stubble, the stubble pulverizer will cover from 25 to 30 acres in a ten-hour day.

Both light and heavy trucks will be used in the campaign to speed up the transportation of supplies, crews and machines from place to place as needed in the progress of the work.

Up to and including the present no better means of combating the borer has been found than by mechanical means. Poisons are ineffective because the borer works inside the stalks. In the moth stage it does not eat, is nocturnal in its habits, and is not attracted to artificial light as other moths are.

By the use of mechanical means the borer can be killed both in the harvested crop and in the remaining refuse. Both ensiling green corn or husking and fine shredding have been found effective in killing what borers would otherwise hibernate in the harvested crop and live to produce another generation. Thorough clean-up campaigns, involving pulverizing the stubble, raking and burning, and plowing under all trash in which borers might hibernate, are the only effective means of controlling the pests which do not happen to remain in the harvested crop.

Individual farmers will be asked to help in the new clean-up campaign as far as their own farms are concerned. An extensive educational program will be carried on prior to March 1 to teach the farmers in infested areas the best clean-up methods and the most effective use of control machinery. This work will consist of educational field meetings, activities of county and local committees in the interest of the voluntary clean-up of the borer, supplying information to the press and distributing educational material through the extension forces. Every possible step will be taken to encourage the individual farmer to cooperate in this campaign and to make it possible for him to do so effectively. The farmers are expected to take the necessary measures before May 1. This date can not be postponed because the borer emerges as a moth soon afterwards, and if not killed before emerging can not be prevented from spreading and doing its damage for another year.

Following May 1 all infested farms will be inspected. When a farm is reported as meeting all requirements of control measures, the individual farmer will be compensated for extra work as provided by the regulations. Such compensation will amount to not more than $2.00 per acre for field

A McCormick-Deering two-row stubble pulverizer in action. It effectively pulverizes the corn stubble, which is the favorite hibernating place for the corn borer, and at the same time destroys any borers in the stubble

corn and not more than $1.00 per acre for sweet corn. In cases where a farm does not meet the requirements of the regulations the federal forces under the authority of the state department of agriculture will conduct the necessary clean-up. The farm cost of such enforced clean-up will be charged to the individual on whose farm the work is done and will be collected on the same basis as taxes by the state authorities.

The corn borer is estimated to be the most dangerous pest that has ever threatened American agriculture. However, forces have been organized to combat it in a manner which will probably be effective unless there are unforeseen developments. It is, though, going to be expensive, both to the individual farmer and to the government. With the $10,000,000 which is to be expended this spring, it is only hoped to check the corn borer and to delay its spread into other territories. It is uncertain what steps may be necessary to take next. Investigations are constantly going on, with the hope of finding some effective control method which can be carried out without the use of additional labor and which will not involve prohibitive expense. At present the most hopeful outlook is for machinery which will harvest the corn economically and incidentally destroy most of the borers, including also better methods of plowing that will leave no trash on top of the ground.

# The Status of Corn Borer Control

EDITOR'S NOTE: The following discussions by L. H. Worthley, Theo Brown, Arthur Johnson, and C. O. Reed are abridgments of extemporaneous talks given at the meeting of the Farm Power and Machinery Division of the American Society of Agricultural Engineers, at Chicago, December 1 and 2, 1926. They present the corn borer control situation up to that time. Since then Congress has passed and the President has signed a bill appropriating $10,000,000 for corn borer control work, which is now actively under way in several states.

## Discussion by L. H. Worthley[1]

THE corn borer probably came to this country in 1909 or 1910 in broom corn. When it was first discovered in 1917, in Massachusetts, it covered an area of about 100 square miles. Research work was carried on for a couple of years and then the government control project was started. After this control work had been going one year in the New England area, it was discovered that there were 2500 square miles infested, and at the present time in that area, known as the two-brood area, there are 5,000 square miles of infestation.

In 1919 there was an infestation discovered in the vicinity of Scotia, N. Y., 25 miles from Albany. The same year, in the fall, there was an infestation found about 35 miles south of Buffalo. Also in Girard township in Pennsylvania the corn borer was found that year.

The following spring a slight infestation was found in Middle Bass Island, in Lake Erie, belonging to Ohio; and following that summer it was found in the townships along the lake front in Ohio and about halfway from the Ohio state line to Detroit in Michigan, on the lake front. That year also there was an infestation discovered in the province of Ontario, in Canada, in Welland County near the Niagara River. Later in the season a much heavier infestation was found in the vicinity of St. Thomas.

That is the history of the spread of the corn borer to date. Two new states were added this year, Indiana and West Virgina. The borer at the present time covers 100,000 square miles. About 90,000 square miles are in the western area, this being a one-brood area.

We thought at first that the two-brood area would show much more damage than the one-brood area, but it has developed that short seasons have a great deal to do with the controlling of the insect in a two-brood area, inasmuch as it does not give the second generation an opportunity to develop. The two-generation area has been showing a reduction for the last three or four years. In the one-generation area the infestation has been steadily increasing. From practically nothing in 1920, it has heached a point where this year, in Ohio, western New York, and southeastern Michigan, we had as high as 40 per cent commercial damage.

The infestation in Canada has been much worse. Starting in 1920, and in 1921 and 1922 scouting work was done in the counties near Detroit, known as Kent, Essex, Lambton, and Elgin, and no infestation was found. In 1923 a very slight infestation was found, not quite one per cent as a whole. In 1924 they had 100 per cent. In 1925 they had two million dollars worth of damage in two counties, and in 1926 the growing of corn was reduced ninety per cent in some cases, and in other cases 75 per cent, and 10 or 25 per cent in the different sections that is left is very severely damaged. Not only are they losing out in their corn production, but the land values are decreasing in several sections from $25.00 to $50.00 an acre.

There isn't any reason why we can't expect something similar to this in the United States in many sections. We may have some sections where it is extremely dry, in which the borer will not show as much damage or as quickly as it does in some of the other sections. However, it is a pest to be greatly concerned about as far as the corn crop goes, and we are looking forward to receiving the help of every man who has anything to do with the corn crop.

There is some misunderstanding perhaps as to the position the agricultural engineer holds in this problem. The entomologists have been working on it for about nine years. They have discovered certain methods of controlling this insect. These control methods require the use of machinery, and this is where the agricultural engineer comes into the picture, to tell us what machinery to use and to design and develop new machinery.

We have been extremely fortunate, from the fact that a large part of the infestation has been in Ohio, in obtaining the services and cooperation of the agricultural engineering department at Ohio State University. We have received the finest cooperation from G. W. McCuen and C. O. Reed of that institution. It has been very gratifying, and I am sure we are going to get the same splendid cooperation in the other states as the program develops.

Also last June here in Chicago we held a meeting with the farm machinery manufacturers. Prof. Reed at that time presented several plans for machinery that might be developed to help control this pest. Many manufacturers attended and have taken hold of this problem in the finest possible way. One concern undertook to develop a combination harvesting machine, and in less than four months this machine was ready for a demonstration, almost an unheard of thing in machinery men helping out in an insect problem. Usually it is about ten or twelve years before we get assistance from any of the machinery men and then the problem is so large that it is almost hopeless to endeavor to control it.

One of the machines developed particularly for this work is known as the stubble pulverizer. The infestation in the stubble is one that gives a great deal of concern, depending largely on the time of year when the corn is to be harvested. If the corn is harvested early and cut fairly close to the ground, say, an inch and a half, leaving a stubble an inch and a half or two inches high, practically no infestation will remain in the field. That is one of the objectives to which we are working. In view of the fact that it will take considerable time to develop machinery and get it into the hands of the farmer, this pulverizer has been developed to take care of stubble until such time as there will be machinery in the hands of farmers to cut the corn close to the ground.

Another machine is the combination corn harvesting machine, one that will cut the stalks to within two inches of the ground, snap the ears, husk them, and either chop or shred the stalk into fine bits, producing at least a 98 or 99 per cent mortality of the insects.

The method of combating the corn borer which we suggest to farmers is that they cut their stalks as close to the ground as possible, and then, if they are to feed the stalks, destroy the uneaten parts or any surplus stalks that they may have in the spring, not later than May 15. If stalks are placed in the silo the insects are totally destroyed during the process

[1]Administrator of corn borer control, U.S.D.A., Bureau of Entomology.

of fermentation. If the stalks are shredded the mortality of the borers is about 98 or 99 per cent. Any surplus stalks that may be around the feed lots or barnyards should be burned no later than May 15. It is a very bad practice to mix the stalks with manure as the dry stalks on top will contain a lot of borers. The borers come up through the moist manure and get into the dry stalks on top, and when the manure is spread in the field they will start working in the spring.

The early maturing varieties of corn planted late do not show as much infestation, and in many cases they have been able to get by with practically no damage, that is, in the badly infested areas.

## Discussion by Theo Brown[2]

Mr. Worthley has pretty well covered the field of what the machinery manufacturers have done. The farm implement manufacturers have been active the past year in cooperating with the government and state officials in adapting corn binders with low-cutting attachments to cut the stubble close to the ground. Corn binders with these attachments are made by International Harvester Company, Massey-Harris Harvester Company, and Deere & Company. The International Harvester Company has designed and built a number of stubble pulverizers for pulverizing the high stubble left by a regular corn binder.

At the June meeting called by Mr. Worthley to present the problem to the farm implement companies, Prof. Reed outlined his idea of a corn "combine" to harvest the crop by cutting the stalks close to the ground, snapping the ears, and then husking and elevating them into a wagon box, and cutting the stalks into lengths of one-half inch or less and dropping them on the ground. As a result of this meeting, Deere & Company designed and built such a machine, and this machine is now in the hands of Ohio State University where it is being tested as to its practicability and effectiveness.

Several plow makers have been active in solving the problem of clean plowing and covering cornstalks completely. We haven't got the okeh of the entomologists yet as to whether absolutely clean plowing will destroy the corn borer, but the implement manufacturers are quite hopeful that such may the case.

I think it is safe to say that agricultural implement manufacturers realize they have a responsibility and have done and will continue to do their share in actively cooperating in the elimination of the corn borer.

## Discussion by Arthur Johnson[3]

The stubble pulverizer, built by the International Harvester Company, is a tractor-driven machine designed to work on two rows at a time. The pulverizing heads consist of a series of arms that are rapidly rotated, with the idea that the stubble will be broken up in small enough pieces to get at every corn borer that happens to be in the stubble. It operates well below the surface of the ground and we think gets all the stubble from cut corn, either cut by machine or by hand. It has its limitations in not being thoroughly efficient in breaking up all the stalks of corn that has been hand picked or machine picked. But it loosens them from the ground so they can be raked up afterwards and burned.

The conditions have been very bad this past fall in the infested areas, and all of us engaged in the work of trying to combat the corn borer have been working under difficulties and have not been able to carry out the programs we outlined for that reason. But the machine I believe will serve a useful purpose, particularly in the fields that have been cut by hand, where the stubble is oftentimes from ten to eighteen inches high.

I want to tell you what has happened in corn borer control work since June (1926). The low-cutting attachments for corn binders, which were developed after two years work,

[2]Manager, experimental department, Deere and Company. Mem. A.S.A.E.

## Discussion by C. O. Reed[4]

have been put on the market by the manufacturers and are now being used and sold in quite large quantities. I want to tell you of the results of the fall work with these low-cutting attachments, which has been followed very closely in demonstration work by E. A. Silver of our staff, who is responsible for following the machines. These are the difficulties that have been found:

1. In both types of machines in the field there is a little tendency yet to pull the stubble, due to the fact that the knife speed is too slow.

2. In one machine there is a tendency for the knife and side plate to clog, because there is too little clearance beneath the cutter bar.

3. In one machine the binder is not cutting low enough: it is cutting two and one-half inches high. In the other machines they are having difficulty in getting traction enough from the bullwheel.

I don't wish to record these as severe criticisms; this is more or less of a progress report. The manufacturers are to be highly commended for the success of these machines. The machines were put on the market and are now being sold in a short time after the design came off the drafting board. There is a market for low-cutting attachments on corn binders. That market is here to stay.

As to the stubble beaters, they are now on the market and are being sold in some quantities.

Mr. Worthley has told you about the combination corn harvesters. This Society should take note of the fact that the John Deere Plow Company in ninety days' time developed that machine from the drafting board to a field demonstration, which in our estimation is an excellent piece of work and an outstanding accomplishment in agricultural engineering.

I wish publicly to make a statement in regard to whom credit is due for this machine. The original idea of the combination corn harvester came from O. D. Long, a corn farmer in Champaign County, Ohio. He suggested the design of this machine not as a corn borer weapon but as a more economical method of handling corn on his farm. Credit for keeping the idea alive and for pushing the matter through until something was done belongs to the department of agricultural engineering at the Ohio State University. Credit for building the machine and putting it in the field belongs to the John Deere Plow Company.

We believe there is a field for this machine, corn borer or no corn borer. We believe there are a number of farmers in the typical corn belt who wish to use fodder, but they will not go to the expense that Ohio farmers go to to get that fodder into the mow. There have been a number of inquiries from Illinois and Iowa as to shocking machines and this combination corn harvester. We believe that when the corn borer strikes the Middle West, where corn is hand picked and the stalks left in the field, this machine is going to be a big factor in allowing the farmers to continue growing corn, handling the corn borer in one operation and keeping the cost down.

Last June we made the statement that if the agricultural engineers didn't look out the whole subject of plowing would be on top of us before we were ready for it, and we have now reached that very status. Certain fundamental things are being laid down by the entomologists to be met by the plow manufacturers. We don't all agree as to just what should be recommended in regard to plow sizes and also in regard to accessory equipment for plows. Steps should be taken to settle this matter soon. It is up to the entomologists to lay down the requisites in the matter of plowing and plowing equipment that must be met. The agricultural engineer must then take the subject up there and provide the equipment to meet those requisites. That is the matter now before us, and it is an extremely live one. Some experimenters have already passed out recommendations which I don't think the agricultural engineers can stand behind.

[3]Experimental engineer, International Harvester Company. Mem. A.S.A.E.

[4]Professor of agricultural engineering, Ohio State University. Mem. A.S.A.E.

# Swamp Drainage For Forestry

By L. F. Livingston[1] and A. E. Wackerman[2]

A NEW type of drainage engineering may be opened up if experiments just begun by the United States Forest Service prove that forest swamps can be superficially drained at a reasonable cost. The Lake States Forest Experiment Station of the U. S. Forest Service which is studying the effect of drainage on timber growth, has found that the growth of the swamp forest is markedly improved after the superficial water in the swamps has been removed. The cost of removing this superficial water is the chief item to be considered. This cost must be correlated with the stand of timber on the swamp under consideration. Almost every type of ditch digging machinery and explosive may have its place in the field.

One of the swamps being studied by the experiment station is located in the upper peninsula of Michigan near Marquette, where the station has an experimental tract. This swamp was ditched by means of dynamite so the effect of the removal of water on the timber growth could be observed. Another swamp on the Minnesota National Forest has been drained and it is planned to drain one or two more swamps as soon as arrangements for carrying on the work can be concluded.

The Michigan swamp is bounded on the south by a roadside ditch. At a culvert outlet, a ditch was located to run at an angle with the roadside ditch until the two ditches were 300 feet apart, then parallel for some 400 feet. This gave a fine opportunity to observe the effect of the ditches.

This ditch was blasted with 50 per cent straight nitroglycerin dynamite using the propagated method. One of the accompanying illustrations shows the type of swamp through which the ditch was made. It is questionable whether any other method would have produced a ditch six feet wide and three feet deep at a total cost of $1.74 per rod. The labor cost was high on this job, $33 per rod, because of extreme weather conditions.

The problem of the swamp forests in the lake states is important not only because of the extensive area which this type of forest covers (estimated to be 9,000,000 acres, or nearly 25 per cent of the entire forest area), but also because the swamps contain much of the virgin timber which is left. These swamps are of low natural productivity and the growth of the swamp forests is exceedingly slow; so slow, in fact, that under present conditions many of them are practically waste lands. Therefore, if cheap methods of improving the growing conditions in the swamps can be devised, one of the important problems of forest conservation will be solved.

The problem is, first, to know what kinds of swamps are susceptible to drainage and what timber yields may be expected from them after they have been improved. Then it is necessary to do the draining at a cost which will not be prohibitive.

[1]Agricultural engineering specialist, Michigan State College. Mem. A.S.A.E.
[2]Assistant silviculturist, Lake States Forest Experiment Station

In the northern European countries of Norway, Sweden, Finland and Russia, where forest conditions are similar to those of the northern lake states, the improvement of swamps by ditching to increase their forest growth is a common cultural practice in forestry. In these countries the forest yields of swamps have been increased until they are nearly as great as the yields from forests on the better upland soils.

Many of the swamps of the lake states were formerly lakes which have now become completely filled with the partly decomposed remains of plants. Around the shallow borders of these former lakes, water lilies, reeds, rushes, and other aquatic plants obtained a foothold and gradually filled the shallow bottoms with their remains. This process gradually extended out into the lake until it was completely filled with plant remains in the form of peat. This filling process is still going on in some lakes as is evidenced by the mat of vegetation or floating bog which surrounds the shore and is gradually closing in upon the center.

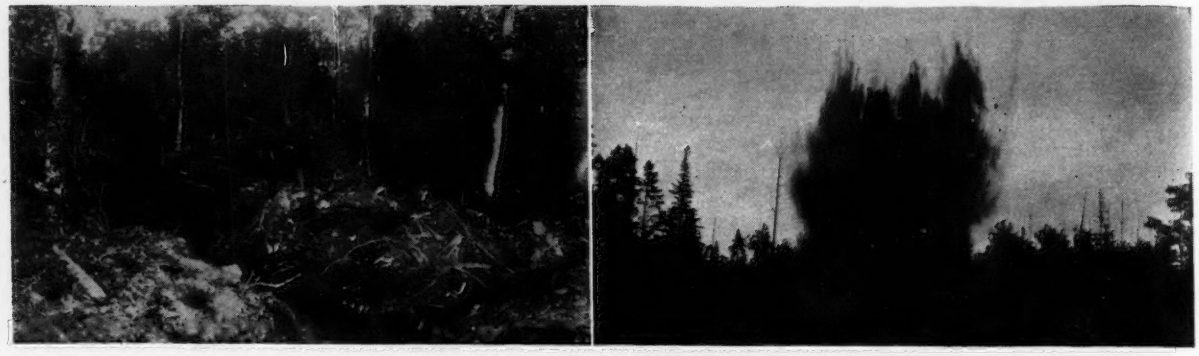
Other swamps not formed from lakes occur in low lands where drainage is poor. This type of swamp "grows" in area and encroaches upon the surrounding upland as the peat becomes thicker and thicker and holds back the water. In certain areas in the Scandinavian countries and Finland it has been found that much of the present swamp area has resulted from these "growing" swamps occupying upland soils. Proper drainage of these swamps not only increases their productive possibilities but also prevents them from invading better forest types and overwhelming them.

The peat soil in most swamps is comparatively shallow, not over 6 to 8 feet deep, although many swamp forests are growing upon peat which is 20 feet and over in depth. It is in the shallow peat swamps that drainage for forestry purposes will be most practicable, because these shallow swamps are the most easily drained and have the greatest potential fertility because of their closeness to mineral soil.

Black spruce, tamarack, and white cedar are the species of trees most commonly found in the swamp forests of the lake states. They may occur in various degrees of mixture or each may occur by itself, as black spruce-tamarack swamps, tamarack-white cedar swamps, or tamarack-black spruce-cedar swamps. These species are all important commercially, especially the spruce which is valuable for paper pulp and the cedar which is used for posts and poles.

The slow growth of trees in swamps is due to a combination of several unfavorable factors. The peat soil which is made up of partly decomposed plant remains contains very little available plant food because decay has not liberated the plant nutrients which are bound up in organic compounds and therefore the fertility of the soil is low. In addition, the partial decomposition results in toxic compounds which retard the growth of swamp plants. Minerals are also scarce

(Left) A view of a timbered swamp in the upper peninsula of Michigan in which dynamite has been planted for a ditch blast. (Right) The ditch formed by the blast



(Left) This shows a blasted ditch connection in the swamp on the experimental tract of the Lake States Forest Experiment Station in Michigan. (Right) Three hundred feet of timbered swamp ditch were made when Col. W. B. Greeley, chief of the U. S. Forest Service, pushed a button at the dedication of the Lake States Forest Experiment Station in Michigan

because the soil is almost entirely made up of organic material.

Then, the wet, low-lying peat soil is often much colder throughout the year than upland soils, freezing early in the fall and thawing out late in the spring. Ice to the thickness of several inches has frequently been found in northern swamps as late as the first of July. With such cold soils swamps offer a much shorter growing season than upland soils which means that the growth of trees is considerably retarded.

Most of the factors detrimental to forest growth in swamps are corrected or improved by the removal of the excess water. Even superficial drainage will improve the forest growth remarkably. The removal of the water permits the soil to warm up and also allows air to enter and furnish oxygen to the roots. The better aeration of the soil also allows bacteria, fungi, and other soil organisms to flourish and decompose the raw peat, thus liberating plant foods in a form available for the plants. Substances toxic to plants are also eliminated by the better water circulation and the more complete oxidation of the organic materials.

The kind of drainage needed in forestry is different than that needed for agriculture. In draining swamps for agriculture it is necessary to dry out the soil sufficiently to permit the use of teams in plowing, cultivating and harvesting. In forestry, on the other hand, all that is needed in drainage is to remove enough of the water to prevent stagnation.

It is not important that the soil be dried out; in fact, it is preferable to keep it quite moist as dry peat is extremely inflammable and creates a serious fire risk. If only enough ditches are put in to carry off the excess water there will be a distinct improvement in the forest growth. Fertilizing, cultivation, and other improvements are not needed for growing swamp forests, once the ditches are put in all that is needed is to maintain them and keep them from clogging up. Improvement of the peat soil then takes place naturally and the growth of the swamp forest increases as a result.

Some preliminary studies in swamps already drained in northern Minnesota for agricultural purposes, but which were not cleared of their forest growth, show in a striking manner the beneficial effect of drainage on forest growth. One swamp about 15 miles northwest of Duluth was drained in 1918 for agriculture and then abandoned. The tamarack and black spruce trees growing in this swamp have increased their rate of growth many times as a result of this drainage. An interesting example is made of one of the tamarack trees. In 1918 this tree was 50 years old, 1.1 inches in diameter, and 10 feet high. The tree hardly grew at all, it merely existed in the exceedingly unfavorable swamp situation. Seven years after the swamp was drained, this tree was 2.6 inches in diameter and 20 feet high and was stil growing vigorously. In the short space of 7 years, this 50-year old tree had doubled its height and more than doubled its diameter.

We know swamp drainage will increase the rate of growth of timber. We know of millions of acres of timber growing swamps. We must find out all the other limiting factors. How far apart will ditches in timbered swamps have effect? How deep must these ditches be? What is the best means of making them? How much will such drainage increase the rate of growth of timber? How much money can be profitably spent by the owners of timbered swamps in drainage?

## A Program of Forestry Research

A BILL introduced into Congress would not only put present forestry research work on an authorized basis, but it would broaden it and establish a foundation for the intelligent direction of public and private forestry.

The bill would give the Secretary of Agriculture power to use funds annually and conduct investigations and experiments briefly as follows:

1. For conducting fire, silvicultural, and other investigations and experiments, to maintain eleven forest experiment stations in different sections of the country, at a cost of not more than $1,000,000.00.

2. For the investigations of diseases of forest trees or forest products and developments of methods of controlling these diseases, not more than $250,000.00.

3. For the investigation of insects injurious or beneficial to forest trees or to forest products and for controlling infestations, not more than $250,000.00.

4. For experiment and investigation to determine the life history and habits of forest animals, birds and wild life, whether injurious to forest growth or of value as a supplemental resource and developing methods for their management and control, not more than $90,000.00.

5. For such investigations as relationship of weather conditions to forest fires as may be necessary to make weather forecasts, not more than $50,000.00.

6. For investigations to develop improved management methods consistent with the growing of timber and the protection of watersheds, not more than $275,000.00.

7. For experiments, investigations and tests of the physical and chemical properties and the utilization and preservation of wood and other forest products, not more than $1,000,000.00, and for similar work with foreign wood and forest products, not more than $50,000.00.

8. To cooperate with appropriate officials of each state and with private and other agencies, in making a comprehensive survey of the present and past requirements for timber and other forest products in the United States and of timber supplies, not more than $250,000.00.

9. For such investigations of costs; returns and the possibility of profitable reforestation under different conditions, of the proper function of timber growing in diversified agriculture, and in insuring the profitable use of marginal land, in mining, transportation and other industries, of the most effective distribution of forest products in the interest of both consumer and timber grower, not more than $250,000.00.

# Michigan's Forest Fire Fighting Flyer

By L. F. Livingston[1]

MICHIGAN at the present time has 11,945,000 acres of idle land, land that is producing neither forests nor agricultural crops. Most of it is adapted only for the growing of trees. Three-fourths of the job of getting these acres back into forests lies in keeping the forest fires out.

Michigan's "Forest Fire Fighting Flyer" was made possible by the cooperation of all agencies in the state either commercial or educational in nature. The railroads in the territory furnished the equipment in both trains that were operated in the lower and upper peninsulas. The train consisted of three cars—one for showing moving pictures and lectures, another for the exhibits, and an accommodation car for those on the train. This equipment was hauled free of charge by the railroads throughout the entire tour. The material for the exhibit car was secured from many sources. The U. S. Forest Service furnished the bulk of the exhibits, the Michigan Department of Conservation, the Michigan State College, the Cleveland-Cliffs Iron Company, and various other organizations interested in forestry and forest fire prevention furnished other material for the exhibit car.

Visitors entering the exhibition car found a darkened gallery in one corner where they saw a spectacular forest fire in full blaze. Bursts of flame and reddened smoke rolled upward most realistically. The burning trees stood out sharply in the glare. The picture was electrically operated.

In the center of the exhibit car in a space of approximately thirty-six square feet was a miniature scene of the Michigan National Forest. In this small space the details were so carefully placed and so vividly portrayed that there was no doubt in the minds of the observers as to what the scene represented. Small pine trees arranged to appear as natural as possible both as to size, arrangement and color almost made one feel and enjoy pine laden breezes. In the center of the small forest was a miniature lake with wooded shores. Guarding the forest from fires were two miniature lookout towers made to resemble the 60 and 80-foot towers now in the forest. On the top of the towers were miniature forest rangers with map boards before them. These men are the eyes of the service, and they are ever on the alert to locate quickly any fire that might occur.

Forest fire fighting methods as employed by the U. S. Forest Service were illustrated by colored picture displays. They showed lookout men on watch, men out battling the advancing flames, crews going into action, the field kitchens at work, and all phases of actual warfare on the crimson destroyer. They also set forth the terrible damage done to forests, stream cover, watersheds, and recreational territory by fires that get beyond control.

The U. S. Forest Service presented contrasting panels showing the beauty and pleasure found in a green forest and the utter desolation left when fires have swept the woods. On one side was a happy camping party, a fisherman in a stream, and wild fire. On the other side were blackened barrens, ugly gullies, a desert barren of vegetable or animal life.

Landowners and organizations desirous of doing private planting of pine were given useful information in an exhibit of the planting stock offered by the Michigan State College and by the State Conservation Department at Lansing.

The cars were placarded with fire warnings of many types and kinds. They included posters put out by nineteen different states and organizations. One of the most striking of these in its wording was that of Oregon. It read, "This is God's country, do not set fires and make it look like hell."

Portable fire fighting equipment used by the Cleveland-Cliffs Iron Company in protecting its hundreds of thousands of acres in the upper peninsula was notable among the exhibits. The display included a small gasoline-driven motor pump weighing 105 pounds and capable of delivering a barrel of water a minute through 1,000 feet of hose at a pressure of 110 pounds, throwing a stream 120 feet from the nozzle. Pictures showed the motor in use.

The motor pump and 2,000 feet of hose are carried on a small motor truck, shown through pictures. A smoke mask used in the front line of fire fighting was a part of the display. Charts presented Michigan forestry and fire control information in striking and easily digested form.

A package of literature, consisting of fully a dozen pieces was given away to each adult who visited the train, and when possible his name and address was secured. Every school child who visited the train was supplied with book marks, pamphlets and posters, and a special effort was made to put this literature in the hands of club workers, boy scout leaders, and school teachers, where it would be effectively used.

The train was made up at the Michigan State College and opened to Farmers' Week where 3,000 people passed through the exhibit car. In Northeast Michigan, thirty-two stops were made on the Michigan Central and the D. & M. Railway, with a total attendance of 18,183.

[1]Specialist in agricultural engineering, Michigan State College. Mem. A.S.A.E.

Two views of the interior of the exhibit car of Michigan's "Forest Fire Fighting Flyer." (Photos by courtesy of the Upper Peninsula Development Bureau)

# The Spread of the Combine*

By F. A. Wirt[1]

HOW far will the use of the combine spread? Can the farmers of the spring wheat, corn belt and humid areas use the combine as they do in the semi-arid sections? If they can't, what is likely to take place on the farms now growing small grain outside of the combine area?

Before discussing the difficulties to be encountered in using the combine in states outside of the Great Plains area and the Pacific Northwest, it might be well to consider briefly the advantages of the combine, for it is in the advantages we will find the explanation of the present spread of the combine.

The combine offers enormous savings in time, in labor and in grain. In a few instances the users say that they have been able to pay for the combine out of the savings made during the first year.

With the new method in the Great Plains area one man operates the tractor, one man the combine and a third and possibly a fourth takes care of the hauling of the grain from the machine to the bin or to the elevator. It is no exaggeration to say that as much labor is required in cooking for the header and thresher crews as is needed in doing the entire harvesting job with the combine. The header or binder methods in the big wheat belts require armies of men from the outside and more horses than are necessary for other farming operations.

In saving grain, it has been found by the users that the combine can be used economically where they would not be justified in going into the field with the binder or header. Of greater importance, they have discovered that they save from two to three bushels more per acre than when using other methods, for every time grain is handled some is lost.

Plowing or lister plowing can follow harvesting from two to three weeks earlier than has heretofore been the custom in many localities. This results in larger yields the following year.

Financing the crop has also been changed by the combine. No longer is it necessary for the wheat grower to go to the banker and borrow the money to feed the harvest hands and to pay them high wages. When the crop is ripe and ready for harvesting, it can be combined and sold as fast as it is cut.

No discussion, however meager, of the advantages of the combine would be complete, without reference to what this remarkable machine has done for the women on the farm. The combine has emancipated women from the drudgery of the harvest. For the women on the farm the combine means fewer men to cook for, no more dishwashing until midnight and many more pleasures and conveniences which have been made possible through the savings of this combined method.

Even against the advice of the manufacturers, farmers in the spring wheat and eastern sections have insisted upon purchasing combines. They realize, perhaps, that they cannot compete with the western wheat grower unless they reduce their cost of production. As they see it, the combine offers the only way out for them in spite of the many disadvantages surrounding the operation of combining east of the Missouri River and north of Nebraska.

**Disadvantages Incident to Combining.** In the Pacific Northwest the early trade developed a sacked grain market. With the introduction of the hillside combine, the mechanical operations of harvesting and threshing on the steep hills of the far West became amazingly efficient. With machines equipped with bagging platform and sacking attachment, grain growers of the Northwest had marked success with their machines. The problem of bulk handling when harvesting steep hillside fields, however, has not yet been solved. In this connection it might be well to remember that in the eastern states much of the grain is grown on rolling, hilly and sometimes rocky fields.

In the Great Plains area, combining introduced the problem of disposal of the grain within, say, a month's time. Before the days of the combine perhaps seventy-five per cent of the grain was marketed in the three months immediately following harvest. With the combine, disposal of the grain becomes a real problem. This last season congestion was noted on the farm, at the elevators, on the railroads and at the shipping ports.

During the past two years we have had good harvest weather in the winter wheat belt, but some believe that we are approaching a wet cycle, in which event we will see the combine given a real test. We may expect more attention to be given methods of drying.

The millers of Kansas and adjoining states have objected to combined wheat in the past, largely because of too high a moisture content. During 1926 there have not been many complaints from the millers, because the wheat was in good

*Abridgment of a paper presented at a meeting of the Farm Power and Machinery Division of the American Society of Agricultural Engineers, at Chicago, December 1 and 2, 1926.

[1]Advertising Manager, J. I. Case Threshing Machine Company. Mem. A.S.A.E.

We cannot as yet actually foresee where the ultimate spread of the combine will end or what its effect on agricultural methods may be. If we were to hazard a prophecy, however, we would say that its effect will be equally as revolutionary and as far reaching as that of the self-binder. In the combine is the greatest lesson in reduced farm production costs through the use of mechanical power and labor-saving machinery the farmer has ever had

condition at harvest time. The elevators and mills are beginning to realize, however, that they must find some inexpensive method of handling combined wheat to prevent heating during wet seasons.

During a wet season it is difficult to harvest satisfactorily by any method. This we have seen illustrated to an unusual degree during the past unusually bad harvesting season in Illinois, the Dakotas, Canada and elsewhere.

In these states and in Canada farmers on one side of the road were using combines and their neighbors on the other side were using the binder and thresher method. In most instances the men with the combines had their harvesting and threshing done when the rains came, seemingly without end, and, as a result, thousands of acres of shocked grain have never been threshed in Illinois. Much difficulty was experienced in the Dakotas and in Canada. On several farms in Illinois this past year wheat threshed with the combine was found to be too damp for safe keeping. In Missouri oat and wheat bundles in many fields rotted on the ground while at the same time the shocks were covered with growing wheat. In several instances in Pennsylvania the wheat obtained from the combine was too wet to store.

In the states mentioned, rains did not come until after the farmers had had an opportunity to combine their grain or, in many instances, to thresh after binding, but those who were unable to thresh at once met with huge losses. It might easily happen that these rains would come a few days earlier, even in normal years. In many of the corn belt and eastern states the rain is rather heavy during the harvesting period.

In eastern Nebraska, for instance, men who are in a position to know, doubt the extensive use of the combine in that section, chiefly on account of climatic conditions. In that section there are comparatively small acreages of wheat. Rainfall in that part of the state during late June is quite heavy. As a matter of fact, it is usually the month of heaviest rainfall. There are some who doubt the spread of the combine into the soft wheat area of eastern Kansas for similar reasons.

In Indiana there is some question as to whether it is safe to let the grain stand until it is dead ripe and dry enough to handle. There is the likelihood of heavy rains and windstorms. In Virginia wheat harvesting occurs in late June and early July when the crops are often down by storms, but in harvesting soybeans in that section the combine should be very successful. In that same state they have had trouble with damp grain even when using older methods. In Maryland the grain will usually contain too much water to permit safe storage. It will be necessary to use some drying device according to an agronomist of that state.

There are crop specialists in some of the states mentioned who hold the opinion that the combine can usually thresh from one to two days earlier after a heavy rain or wet spell than can the thresher which is handling the grain direct from the shock. This, of course, stands to reason for bundles in the shock could hardly dry out as rapidly as the standing grain. Too long a delay, of course, would be the cause of considerable bleaching and much shattering.

In Canada combines have been used under very severe conditions. Quoting from a Canadian newspaper, "Last fall Mr. Hughes used his combine for the first time. It was an ideal test year as the weather was so stormy that harvesting and threshing were delayed for almost eight weeks. Conditions could hardly have been worse. Mr. Hughes pulled into his field on October 5 and finished on November 9. He combined 250 acres of badly storm-beaten wheat after the long succession of cold, drenching weather, including a snowstorm, and got all of it. Delivered at the elevator he was given a straight grade on all he produced."

At one point in Alberta a combine user was completing a 200-acre field late in September which had been started over a month before. Late in October another user in Alberta was combining grain very badly bleached on account of standing in the weather so long. The grade was low but we are informed that a farmer in the same locality who had cut his grain with the binder and who had been forced to let it remain in the shock found that his grain threshed at that time was grading almost as low as that handled by the combine.

In sections where the combine has been used for several years it has been discovered that the critical year with the combine is the first year. In changing from the binder, or more especially the header, to the combine, the farmer gets nervous and does not delay combining, but begins too soon. This short delay is extremely important in the East and North. For example, on July 10 in Ohio a sample of wheat described as dead ripe but not shattering contained 29.9 per cent moisture. Two days later the wheat was standing well but shattering was beginning. The moisture content was 14.3 per cent. Plots left to stand until July 17 contained a moisture content of 12.4 per cent, which of course was safe. Some shattering had occurred but in these particular instances it was too little to affect the yield.

From the experiences of the past few years we may draw the following conclusions:

1. Harvesting should not be begun too early
2. During bad years the combine will not have much more difficulty than the binder
3. Some drying method must be made available at the mill or elevator, also at the farm
4. A nonshattering, stiff straw grain must be developed by the plant breeders

**Weeds.** Spring wheat as grown in the Northwest and Canada usually contains many more weeds than winter wheat. It is in the spring wheat country where we hear so much about dockage. Until something is done to decrease the quantity of weeds in spring wheat, combining will be difficult. It should be noted that in the Northwest weeds are becoming a more serious menace every season. In many wheat fields, thistles and other weeds are green at the time of harvesting. Green weeds will smash more or less as they go through the machine, making the grain decidedly wet, increasing the moisture content and increasing, also, the chances of damage unless the grain is dried. Grain full of dockage is always more likely to bin-burn than the same grain without dockage.

Observers have already noted that wheat full of weeds and weed seeds looked very dirty as it came from the combine, but with drying in the granary it assumed more of its usual appearance.

Ripe weed seeds can be separated by a suitable screen, in which case they are not placed back on the land. It should not be forgotten, however, that in the East much of the threshed straw containing weed seeds is used for bedding and the seeds are then put back on the land. So far as ripe weed seed is concerned the combine does not suffer in comparison with other methods of harvesting and threshing.

One of the worst weeds in some localities is the perennial sow thistle. This is most readily controlled by plowing immediately after the grain is cut, an advantage offered by the combine.

**Windstorms and Hail.** In many localities there is considerable likelihood of hail before the wheat harvest is completed. Oftentimes the hail will completely destroy the crop which, if harvested a few days earlier, would have been very profitable.

Lodging of ripe grain, as everyone knows, is quite a problem in many states. The delay brought about by the use of the combine increases this hazard. Experience with binders and combines already indicates that the combine is the better machine for picking up the down grain. With the combine the operator can adjust the cutting bar to within a very few inches of the surface of the ground and many a magnificent job of cutting can be done, where the man with the binder would either cross the field cutting one way only or would not even tackle the job.

To overcome damage from hail and windstorms and to give the weeds an opportunity to dry out, Thomas D. Campbell of the famous Campbell Farming Corporation, of Hardin, Montana, has developed a pick-up method which he is using with considerable success. Much of Mr. Campbell's grain is cut with grain binders from which the binding attachments have been removed. Usually four 10-foot binders are hitched in tandem and arranged with the carriers so that the headed grain is dropped in a windrow. While in the windrow, damage from hail and windstorms is no greater, probably, than when the crop is in the shock. During this same period, green weeds can be drying out. A few days later a combine with pick-up attachment is driven along this swath. This method

has several advantages where the yield is not too heavy, big acreages must be covered quickly and the risk of hail, windstorms and weeds is rather high.

**Saving of Straw.** In many of the corn belt and eastern states, the farmers are anxious to save the straw for bedding purposes. It is quite a problem to adapt the combine to such circumstances. First of all, it requires a straw dump and a satisfactory as well as economical method of gathering the straw for housing or stacking. To leave the straw in the field would be so objectionable to many farmers east of Missouri that they would probably forego the advantages of the combine unless the straw could be saved.

Where saving the straw is a big item, it will be necessary to cut close to the ground which, in turn, means that a large amount of straw must be handled by the separating mechanism.

Many operators will not pay sufficient attention to their instruction books; consequently they do not follow the instructions given in regard to threshing crops other than wheat. The results under such circumstances are far from what they should be and it is possible for the users to become dissatisfied when it is really the fault of the operator and not of the machine.

**Investment.** A sixteen-foot combine costing over $2,000 according to users, is a worth while investment for the grower of from 160 to 200 acres of grain. The machine is likely to be used for custom work in addition to the above but this size is likely to be too big for the corn belt and eastern states, although it should be well adapted to much of the Dakotas and the western provinces of Canada.

Smaller machines cutting nine and ten-foot swaths, operated by a power take-off, have been developed and sold in small quantities by different manufacturers. These are not hillside machines, yet much of the grain in the corn belt and eastern states will be found on hilly and rolling land. The power take-off under such conditions, and even under more favorable circumstances, probably does not offer the best method of driving the heading and threshing mechanisms. The smaller machine offers a lower investment which, taken with the smaller acreages, is very desirable.

For eastern conditions the grain bin is satisfactory if the fields are level, but if rough a wagon is likely to be more valuable than either the grain bin or bagging attachment, in spite of the fact that in many of the eastern states most of the grain is bagged.

**Grains Which Can Be Combined.** Wheat is the easiest crop to combine. With oats there is likelihood of crinkling shortly after they are ripe. Consequently, in many states it probably will be necessary to harvest the oats before they are dry enough to bin. This, however, does not hold true in the drier regions where the combine already has been successfully used for harvesting oats.

Both barley and rye have been combined successfully, although it is thought that it may be necessary to harvest barley before it is dry enough to bin with safety.

Some tests have been made in combining rice. The big problem with rice is that of drying. The combine properly adjusted will perform splendidly without hulling over 3 per cent, which is low, yet the moisture content at that time ranges from 19 per cent upward. The safe moisture content is around 14 per cent or under, 12 to 13 per cent or less being preferable.

Most of the rice mills have driers, but only from 1 to 1½ per cent of this moisture can be removed at a time. Therefore, to dry rice from 20 per cent moisture content down to 14 per cent involves from four to five dryings. For all practical purposes no experimental work has been done with the drying of combined rice. It would appear from the facts at hand that rice will be the last crop to be successfully combined, if combined at all.

Harvesting soybeans is done most efficiently and economically by the combine. Tests made at Illinois and elsewhere indicate that this machine offers by far the best method of harvesting soybeans, yet occasionally we have weather conditions such as have existed this year. Both in Illinois and Mississippi they have had so much rain that not even the combine could be used in the fields. But when the fields and the beans do become dry, then they can go into the fields. In the meantime, beans cut with binders and mowers have rotted down.

Sweet clover has been harvested and threshed with the combine. The trouble here is in feeding bulky material to the cylinder, but by careful adjustment of the machine and suitable attachments, sweet clover can be threshed satisfactorily.

It is estimated that 50 per cent of the grain sorghum crop will be harvested by hand methods, 35 per cent by headers, 5 per cent with combines and the remainder by various combinations of machine and hand methods. Farmers who are using the combine for harvesting kaffir have found it to be satisfactory. Many use this machine for stationary threshing of grain sorghums cut by other machines. We may expect increasing use of this machine for this crop, although the problem of drying again enters in.

Flax is another crop which has been successfully combined in the field.

## CONCLUSIONS

1. The obstacles to be overcome before the combine can be used satisfactorily on a big scale in the corn belt, the eastern United States, the Northwest, and in the western provinces of Canada are a challenge to the plant breeder, the agricultural engineer, the state agricultural experiment station, the U. S. Department of Agriculture, and the manufacturer.

2. Grain growers not possessing the advantages of the combine must greatly reduce their cost of production. Much can be don through the better use of present harvesting and threshing machinery, but the use of the combine is spreading. The movement will go far, provided the disadvantages can be overcome.

3. To the plant breeder we should look for the development of early-maturing varieties of grain possessing the characteristics of stiff straw and nonshattering heads.

4. To the agricultural engineer we should look for information on inexpensive grain drying equipment, information which can be widely disseminated in the immediate future. Also we may expect from the agricultural engineer combine schools where combines are now being used, also grain binder and thresher schools where the disadvantages of the combine have not yet been overcome.

5. From the millers and elevator operators we have a right to expect the installation of drying equipment to handle damp grain in quantity.

6. To the agricultural experiment stations and to the U. S. Department of Agriculture we should look, next year and the years immediately following, for valuable information on the profitable utilization of the combine.

7. As for the manufacturers, we can depend upon them to continue, as they have in the past, their extensive experimental work with the combine—the machine which offers, where it can be used, the cheapest known method of harvesting and makes possible tremendous savings in time, labor and grain.

# Efficiency in Haying Operations

TIME-HONORED haying practices are often inferior, according to the results of studies of the subject by L. A. Reynoldson, economist, and C. D. Kinsman, agricultural engineer, of the U. S. Department of Agriculture. Aside from being a bulky product, hay requires so much attention and handling within a comparatively short season that the question of efficiency handling is largely a mechanical one.

The manner in which the most hay can be handled according to the best practices and with the least labor depends on many variable conditions such as the kind of hay, yield per acre, quality desired, topography of the land, quantity produced, and distance from field to stack. Observations made of various methods and equipment in use under different conditions showed widely varying labor requirements. In Nebraska a method is in use whereby four to five tons of hay can be taken from the stack, put on a wagon, and pitched off into the feed lot in about one hour.

Detailed information on this subject is available in Farmers Bulletin 1525-F, entitled "Effective Haying Equipment and Practices." This bulletin may be had upon request to the U. S. Department of Agriculture, Washington, D. C.

# Results of the U. S. D. A. Investigation of Harvesting with the Combine*

By C. D. Kinsman[1]

RESPONDING to numerous requests for information on the adaptability and limitations of the combine for harvesting crops in humid areas, the U. S. Department of Agriculture undertook a survey of the subject at the beginning of the 1926 harvest season. In order that all phases of the problem should be studied, the services of three bureaus in the Department were enlisted, those represented being the Bureau of Public Roads, the Bureau of Agricultural Economics and the Bureau of Plant Industry.

As outlined at the start of the study, the subjects on which it seemed most desirable to obtain information included adaptability of the combine to various crops; its acreage limits; its relation to climatic conditions; the general economy of various harvesting methods including losses; mechanical problems of the combine; and storage and milling problems.

It was evident at the start of the study that certain of the information could be obtained most satisfactorily in the field through observation of the machines in operation or by making inquiry of the owners or operators, while other of the information desired would necessarily need to be obtained through controlled experiments either on experimental plots or in the laboratory. In order to obtain a more complete picture of the problem as a whole, it was decided to start the field work first and follow with whatever laboratory and controlled experiments were later found necessary.

For the purpose of obtaining cost data and general information on the effect of the use of the combine on farm organization, a questionnaire was prepared to be used in interviews with owners and operators at the end of the harvest season and since reliable information can only be obtained when a practice has been in use for some time, it was decided to conduct these interviews during the first year in the wheat-producing areas where the combines were first introduced east of the Rocky Mountains. Having in mind typical areas in each section where comparable information on harvesting costs by means of the binder, header and combine could be obtained, the following localities were selected: Panhandle section of Texas; Alfalfa County, Oklahoma; Ottawa County, Kansas; Grant County, Nebraska, and the Judith Basin section of Montana.

Representatives from each of the cooperating bureaus formed a field party and started work in Oklahoma and Texas at the beginning of harvest early in June and worked northward as the season advanced. While the harvest was under way observations were made of ripening of the different varieties of grain grown in each region, the weather conditions, and the losses resulting from each of the methods of harvesting. When the harvest was completed a portion of the party moved to the next area selected while the rest of the party remained to obtain cost records. Representatives from the agricultural colleges in Texas, Oklahoma, Nebraska and Montana assisted in the study in their respective states during the wheat harvest, and from Oklahoma and Kansas during a study of grain sorghum harvesting methods later this fall. At the same time representatives of the Division of Grain Investigations and of the Division of Agricultural Engineering were observing storage condition of the combined grain and conducted two grain-drying experiments, one at Hayes, Kansas, and the other at Havre, Montana. The author spent a part of his time with the field party and in conducting the drying studies, and the remainder of the harvest season in a scouting trip through other states where combines are in use.

**Results Obtained.** Any information given out at this time regarding results of the combine study can be considered only as a progress report. However, I feel ready to state, after four months observation of the operation of combines in twelve different states and receiving reports of their operation from several other states, that rainfall is not necessarily a limiting factor for the combine, and that as more information becomes available regarding when and how to use combines, they may be used successfully wherever grain binders are now used, and that the manufacturers of combines may consider all of this territory as a possible field for sales. This should not be taken to mean, however, that I believe the combine will entirely supplant the binder in all localities as there are other factors that undoubtedly will limit the economical use of the combine in some areas, such as extremely small acreages of combine crops grown and the possible necessity of keeping a binder for the harvesting of crops that can not be handled with the combine.

**Crops Harvested With Combines.** Very little grain other than wheat is cut by the combine at the present time in the Great Plains area, although some farmers reported cutting small acreages of oats, barley, rye and flax, and in the Panhandle section of Texas a considerable amount of grain sorghums is so harvested. In the more humid sections, such crops as sweet clover, alsike clover, alfalfa and timothy, in addition to sorghums, are harvested by the combine, but so far we have obtained no detailed records in the area where these crops are grown.

**Duty of Combines.** The annual capacity of a combine is determined by its daily capacity and the length of the harvest season. The daily capacity is affected mainly by the width of cut, the speed of travel, the hours of operation and the amount of time lost in caring for the machine. emptying grain, turning at the ends and in making repairs and adjustments, while the length of season is determined largely by the kinds and varieties of crops harvested and the weather conditions during harvest.

The best measure of rate of cutting for purposes of comparison probably is that of acres cut per hour per foot of width of cut. Considerable variation was found to exist in this factor for different sizes and makes of combines. A part of this variation was due to differences in rate of travel and part to time lost due to imperfections of the machine. Most of the farmers interviewed were using their first machine and had had no prior experience with combines, which may also in part account for the variations in capacity. The average acreage cut annually by each size of combine on which reports were obtained is shown in Table I. The acres cut per hour and per foot in width were also calculated.

The rate per cut per acre per foot ranged from 0.19 to 0.26 acre per hour, with an average of 0.22 acre, just slightly under one-quarter acre per foot width per hour. These computations would indicate that where a nine or ten-foot

**TABLE I. Acres Cut Annually with Combines of Different Types and Sizes**

| Type of machine | Farms, number | Width of cut, feet | Average annual acreage cut per machine: Own grain | Custom cutting | Total | Acres per feet width of combine |
|---|---|---|---|---|---|---|
| Combines with power take-off | 25 | 8 | 214.7 | 60.0 | 274.7 | 38.4 |
| | 10 | 10 | 292.5 | 164.5 | 457.0 | 45.7 |
| Combines, with auxiliary engines, pulled by tractor | 56 | 12 | 301.2 | 107.3 | 408.5 | 34.0 |
| | 51 | 15 | 377.8 | 196.3 | 574.1 | 36.3 |
| | 104 | 16 | 427.5 | 254.3 | 681.8 | 42.6 |
| | 3 | 20 | 700.0 | 376.7 | 1076.7 | 53.8 |
| All modern tractor pulled machines | 249 | | 365.5 | 187.7 | 553.2 | 39.2 |

*A contribution to the combine symposium presented at the meeting of the Farm Power and Machinery Division of the American Society of Agricultural Engineers, at Chicago, Illinois, December 1 and 2, 1926.

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[3]Assoc. Mem. A.S.A.E. Extension Associate Professor of Agricultural Engineering, Iowa State College.

[4]Charter A.S.A.E. Professor of Rural Engineering, Cornell University.

combine is used the cost of harvesting an annual acreage of around sixty acres the cost per bushel is practically the same for either the binder or the combine. In other words, with the small combines now on the market, the cost figures—just cost alone—per bushel would indicate that it becomes a profitable investment at around sixty acres. That is a smaller figure, I think, than has been accepted before, but it is the result of our studies this past summer. For an annual acreage smaller than this it is probably cheaper to use the binder and for larger acreages the combine under most conditions is the cheaper. As the acreage increases the relative cost of harvesting with the combine rapidly decreases until for an annual acreage of four hundred acres the cost per bushel with the combine is approximately two-fifths that of the binder and stationary thresher.

Just what the maximum acreage is that an owner of a small-sized combine can expect to harvest annually in the humid areas where small farms and small acreages of crops prevail has not as yet been determined. In the wheat areas studied the average acreage of wheat harvested with the small size of combine is around four hundred acres, or about forty acres per foot of width of cut of the combine. As a matter of fact, that is the average acreage for all sizes of combines. It will vary somewhat with different sizes, and, of course, with the power unit, or tractor, that is used. If there is plenty of power, and if the ground conditions are better, one may drive a little faster. But it will average around forty acres per foot width of cut. It is reasonable to believe that the same size of combine used farther east could be depended upon to cut annually at least half this acreage of one crop.

**Elements of Cost in Harvesting With the Combine.** The items entering into the cost of operating a combine include both fixed costs which are independent of the acreage cut annually and direct operating costs which vary with the amount the machine is used. In estimating the cost of operation, interest on the investment, depreciation, taxes, insurance and housing were entered as fixed costs and amount to approximately $200.00 a year for a ten-foot combine. The operating costs consist of fuel, oil, labor, repairs and the charge for the power to pull the combine. All of the operating charges taken together amount to approximately $1.25 an acre for a wheat yield of twenty bushels per acre. The fixed costs for the larger combines is somewhat higher but the operating costs are very nearly the same as for the ten-foot size. Fig. 1 shows the approximate cost per acre of harvesting a 15-bushel yield of wheat by means of binders, headers and combines for different total acreages harvested annually, both fixed and operating expenses being taken into consideration.

**Fuel and Lubricants Used.** The amount of fuel and lubricant used in operating the combines varied somewhat according to the size and make of machine and whether it was driven by an auxiliary engine or was of the power take-off type. With one or two exceptions gasoline was used in the auxiliary engine, while the fuel used in the tractors was about equally divided between gasoline and kerosene, although a few operators used distillate.

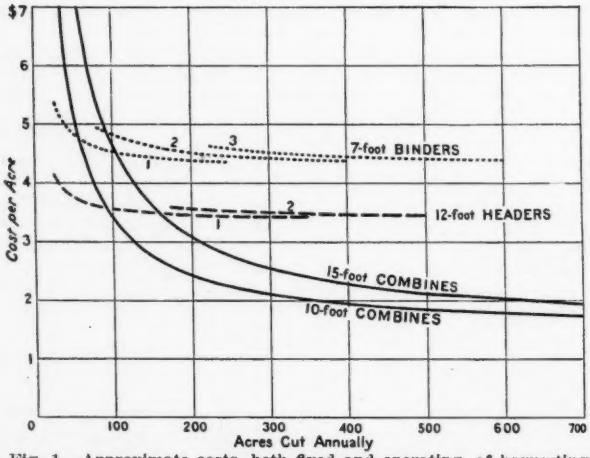


Fig. 1. Approximate costs, both fixed and operating, of harvesting a 15-bushel yield of wheat with binders, headers, and combines

The average fuel per acre on a 20-bushel yield was 1.4 gallons. It did not make much difference whether gasoline or kerosene was used. At an average of 18 cents a gallon, it cost about 25 cents an acre. Oil and grease amounted to slightly under 10 cents an acre. As to repairs on the combine, our information was very unsatisfactory, for the reason that about ninety per cent of the combines have been out only a year or two, and the repairs on a machine of that age are no indication of what the repairs are going to be later on. Taking the older machines only, we found that the average repair cost was somewhat under 10 cents an acre, or, including the labor of making repairs, it was about 15 cents an acre, and I think that that is a safe figure to use.

To get the other items of this dollar and a quarter, we made a charge of 50 cents an acre for the tractor; and the labor, where one man is operating the machine, will not amount to over 25 cents an acre. Of course with two men the charge is higher. The foregoing items together give $1.25.

The total cost per bushel, say on 100 acres, amounts to about 16 cents; on 300 acres, about 10 cents; and on 500 to 600 acres, about 8 cents a bushel. That does not include hauling. In our studies of all the methods of harvesting we decided to separate the hauling from the harvesting, because the hauling of the grain really is a marketing proposition.

The average first cost of the different sizes of combines as reported by the owners was $1995, ranging from $1043 to $3315, and their estimate of years of service they would be able to obtain was from 5 to 11.7, averaging 8.3 years.

**Efficiency of Combine Operation.** One of the most favorable reactions I received during my observations of the combine was the efficiency with which most of the newer machines handled wheat even under adverse conditions. Blanket tests of grain carried over indicated that on the average this loss was no greater for combines than for stationary threshers, though the operating conditions were much more severe. Under really adverse conditions, where special adjustments of the machines seemed necessary, there was considerable difficulty in getting the machines adjusted to do their best work.

When threshing other crops, however, the combines were not usually operating as efficiently. Most of the combines when delivered to the farmer are adjusted for harvesting wheat and it seems that the operators either are hesitant about making changes or adjustments when working on other crops or they do not understand the proper adjustments necessary. I feel that there is a decided need for educational work regarding the proper operation of combines for the different crops and particularly is this needed when harvesting under adverse conditions.

We found in a grain sorghum study in the Panhandle section of Oklahoma and Texas this fall that there was a large number of combine owners using their combines for harvesting the grain sorghums, but a very small percentage had them properly adjusted to do efficient work. Many of them apparently had not read their instruction books at all and very little effort was being given by the dealers to aid the farmers in improving the operation of their machines.

In the harvesting of grain sorghums, there is a tendency to crack the grain, and for that reason it is necessary, or desirable, to slow down the cylinder considerably, and some of the companies—in fact, I believe all—recommend putting on a special sprocket so the cylinder may be run slower without slowing down the rest of the machine. We found in all that area just one machine so equipped, and we were unable to locate a single dealer who was carrying any special sprockets for that purpose. In fact, of all the dealers we visited only one even knew there were such sprockets. Most of them told us there wasn't such a thing until we got their repair catalogue and showed it to them.

One of the disadvantages of the combine frequently mentioned is that of the delay necessary while waiting for the crop to get sufficiently ripe for cutting with the combine. Replies obtained would indicate that the danger of losses during this period is overestimated by the inexperienced per-

son, as very few owners reported any serious losses that could be attributed to this delay. I prepared a table that shows the days of delay as reported by the farmers and the combine operators—the number of days delay over what they would have expected if they had used a binder or a header. This ranged all the way from the report of one farmer with a header that he went in right away—there was no delay whatsoever up to as high as fourteen days delay, the average being just under ten days with the binder and five and one-half days with the header. There is that much delay in order to use a combine.

Losses of grain resulting from the different methods of harvesting were determined in Oklahoma, Kansas, Nebraska and Montana by actual count of the number of heads left on the ground in 259 fields cut by combines, 59 fields cut with headers, and 34 fields cut with binders. The yield per acre in fields cut with combines was determined from samples taken previous to harvesting. The losses on headed and bound fields were calculated on the basis of yields obtained from the combined fields.

Forty-one of the 190 fields of winter wheat cut with the combine had losses of less than one per cent, 106 less than two per cent, and 137 less than three per cent. Losses greater than three per cent occurred with an uneven or partly lodged crop, on rough land, with poor machines, through careless operation, or in very windy weather. The average loss from harvesting winter wheat with combines was 2.6 per cent. Fields cut with headers showed an average loss of 3.3 per cent, while fields cut with binders showed an average loss of 6.1 per cent. These losses are based on a yield of 20.4 bushels per acre. The loss per acre was 32 pounds after the combine, 40 pounds after the header, and 74 pounds after the binder. Heads cut off and dropped on the ground were the greatest source of loss in combining and heading. Additional losses in heading occurred in loading the header barge and hauling to the stack. The losses in binding include the cutting loss, the loss between the canvasses, losses from the binding platform, bundle carrier heads dropped in shocking and hauling, and heads left in shock bottoms. Some additional losses due to shattering during cutting and in hauling are not included as sufficient counts on these items were not obtained.

The relative quality of grain obtained when harvesting by the different method is also a factor to be considered in the adaptation of the combine to humid conditions. A large number of grain samples and other data on this subject was obtained during the summer but the analysis of this information has not been completed as yet.

Our plans for next year (1927), from the agricultural engineering standpoint, cover three phases of the subject as follows:

1. The proper operation of the machine for each crop, under various conditions. That is, what are the proper speeds and adjustments of the machines to get the best results?
2. What changes in the machine are necessary to get satisfactory results?
3. Drying experiments.

## Discussion

**E. A. Hunger**[1] You spoke about 60 acres being a minimum profitable acreage to work with the combine. Have you noticed in your interviews whether many of those farmers—say, two or three—go together and buy a machine of that kind, or are there many of them doing custom work to spread out that expense and increase the earning power, even though they might have a smaller acreage? Is that very prevalent?

**Mr. Kinsman:** Yes, it is more a case of custom work than the cooperatively owned machine, except where the machine may be owned in the family, that is, among relatives; it can be used satisfactorily that way. But I would say that at least ninety per cent of the owners use the machine for doing some custom work. Some of them do as much custom work as they do of their own work. That really gives them a larger acreage than it is possible to handle with the combine. That comes about for two reasons: First, because they naturally cannot tell in advance how uniformly their crop is going to ripen, and it depends on how uniformly it ripens as to what acreage they can possibly handle with the machine. Second, if they are doing custom work, they can pick their customers and take them as their crops ripen, while if it was all their own grain, they would have to take that grain at that moment.

**Mr. Hunger:** I was out this fall interviewing quite a number of farmers who are using the combine in soy beans, and practically every one of them was doing some custom work. This was in Indiana and Illinois.

**E. A. Hardy**[2]**:** We find that it is difficult for us to figure depreciation per year, because so many of our machines are cutting anywhere from 300 to 1400 acres per year, and I was wondering what unit Mr. Kinsman was figuring in depreciation and with regard to repairs. Our people who have been using machines for two or three years have so far very small repair charges, and I would like to have a little guidance with regard to estimating the repair costs.

**Mr. Kinsman:** So far as repairs are concerned, we have found, just as Mr. Hardy says, that the first two or three years the repairs do not amount to very much. We grouped our combines according to ages, the number of years they had been out. We grouped each age separately and took the 1926 repair bill, found out what the average was for each combine, one year, two years, three years and so on up to eight or nine years of age. We found that after about four years the cost runs about uniform, that is, from four years on it doesn't vary materially. And while it varies considerably in different areas and with the different individual machines, yet we felt that 15 cents an acre would cover both repairs and labor.

As to depreciation, that is extremely unsatisfactory in any record so far obtained. The average estimated life of the combines is 8.3 years, of all the combine owners interviewed. However, the older the machines were, the higher the estimate. Of course, some of the shorter life machines would be eliminated in the first few years and we would expect the owners of the older machines to have a slightly higher estimate, but what I think is really the reason is that, when a man first gets a machine and has had it only a year or two, he thinks that in six or seven years it will be about done, that that is a good life for a machine; but after he has run one six or seven years, he finds there is considerable life left in it yet. We found men who had owned machines for seven or eight years who said they could see no reason why it wouldn't last that much longer, or even ten years longer.

I would say that the amount the machine is used apparently has only a relatively small effect on its life, that is, the life estimated by the owner. So far as I can see, they base their estimate more upon how soon they would like to have a new model.

But we have felt that from ten to twelve per cent annual depreciation would cover depreciation charges satisfactorily.

**A. W. Clyde**[3]**:** I have just been figuring on the capacities you mentioned and the speed of cutting. Am I right that about twenty days' work is about the most a combine would be expected to do in a year?

**Mr. Kinsman:** Of course, our study was confined almost entirely this year to the wheat section, where wheat is the only crop harvested by the combine, and twenty days is about the average number of days it is in use. That would include about ten or twelve days home work and eight to ten days custom work. In the wheat section about the only other crops are oats and barley. We found only two or three men attempting to harvest oats in that area, largely because of the extremely small acreage; they had their old binders and they felt they could cut their oats before they were ripe enough to begin on them with the combine, and so get done ahead of the wheat crop. Also, they wanted the straw and they weren't entirely satisfied that they could save the straw satisfactorily with a combine. Practically none of them had ever heard of a straw dump attachment for the combine.

The Panhandle section is both a wheat and a grain sorghum area, although the grain sorghums are produced more on the sandy land and the wheat on the hard land. We found men there who harvested 500 to 1,000 acres of wheat with

[1]International Harvester Co.

[2]Mem. A.S.A.E. Professor of Agricultural Engineering, University of Saskatchewan.

the combine and then 200 or 300, or maybe 400 or 500 acres of grain sorghums this fall. Wherever the harvesting seasons for the two crops do not overlap, there is no reason why they couldn't extend the period through the entire fall.

But I would say for wheat alone in that area that 20 days is about all they can expect to be able to spend in the harvesting. As you come farther east, it probably is less than that, probably scarcely exceeding half of that, unless they are raising two different varieties that ripen at different times of the year.

**H. W. Riley**[4]: How does the combine behave with oats? Will there be very great loss in attempting to thresh oats that are none too ripe?

**Mr. Kinsman**: In Iowa (at Ames) they used a combine this year for harvesting oats and harvested them just as green as they could have been cut with a binder, and then they dried them. We found one man harvesting oats in North Dakota, just west of Grand Forks, who was using his combine at a time when it was too wet to use a binder, although the oats were ripe, and he was simply piling them on his haymow floor. He had, I think, something over 2,000 bushels threshed at that time and was having no serious difficulty in drying them out in a few days by shoveling them over occasionally. We occasionally ran across men using the combine for oats, apparently without any serious difficulty, providing the weather conditions were right.

There was another question asked about the total losses with the combine as compared with the grain when cut with a binder and threshed with a stationary thresher. We got some records on that, but these have not been completely worked up. I will say, though, that we are surprised at the increased yields of combined grain. There is a much greater loss than we had appreciated when the binder and stationary thresher are used.

[4]Professor of Rural Engineering, Cornell University. Charter A.S.A.E.

# Field Tests of the Combine in Illinois*

By I. P. Blauser[1]

THE first combine in Illinois was used in October 1924 by Garwood Brothers, of Stonington, to harvest soybeans and the soybean crop is in fact responsible for the introduction of the combine into the state. Soybeans had been causing so much trouble in harvesting that practically every machine that is used in harvesting other crops had been given a trial in an endeavor to find an efficient and economical method. Questions were raised as to what could be expected of the combine under less favorable conditions. The last two seasons have been especially wet, and have given the combine a real test.

At the present time there are between sixty and seventy combines in Illinois. At the same time last year there were twelve. Judging from the amount of grain that rotted in the shock this year, the increase in the number of combines in Illinois will probably be greater next year than it was this. There are three makes of combines being sold in the state at the present time. There was one other make given a trial in harvesting soybeans, but so far as I know none has been sold. This combine is quite different from the other makes in that it is mounted on a Fordson tractor, and receives its power through a power take-off.

Having made such a good showing in soybeans, the question was raised whether the combine could not be used for harvesting the small grain crops; if so, this would make it possible to use the combine on smaller farms. The saving in time and labor is an item of considerable importance in favor of the combine, and the more acres that can be harvested per year with the combine the less will be the overhead charges per acre. By handling crops that ripen at different times of the year it is possible to harvest a greater number of acres. Some crops such as soybeans and sweet clover have been especially difficult to harvest by the usual method of cutting and threshing in separate operations, because of mechanical troubles and high losses.

Efficiency tests were made of a number of combines under actual field conditions. These tests were made by catching the straw and chaff in a canvas and at the same time catching the grain in a bag. The loose and unthreshed grain in the chaff and straw was recovered by rethreshing the material in a 16-inch double-cylinder thresher. The loss back of the cutter bar was determined by picking up all the grain back of the cutter bar in areas one yard square at the place where the straw and grain were caught. The yield per acre was determined by measuring the width of cut, and the distance covered in the test.

In soybeans losses by other methods may run as high as 45 per cent, and in many instances during the past two seasons the entire crop has been lost—some were never cut and others rotted in the shocks after they were cut. While the wet weather of the past two seasons has made it more difficult to harvest, the combines have had far better results than any other method. During the last two years the results from twenty-four tests show a total loss of only 8.89 per cent. At the same time samples threshed with the combine gave a much lower moisture percentage, and a higher germination percentage. These tests were not made under the worst conditions nor were they made under the best. Weeds cause some difficulty, especially where the weeds are tall and the soybeans short. The reel must be set low enough to get the beans and then it is too low for the weeds. Bull nettles which have fruit varying from ⅜ to ¾ inches in diameter cause considerable trouble, because they are difficult to get out, and many are mashed, not only giving the beans a bad appearance but also adding to their moisture content. The bar type of cylinder met that condition a little

*A contribution to the combine symposium presented at the meeting of the Farm Power and Machinery Division of the American Society of Agricultural Engineers, at Chicago, December, 1926.

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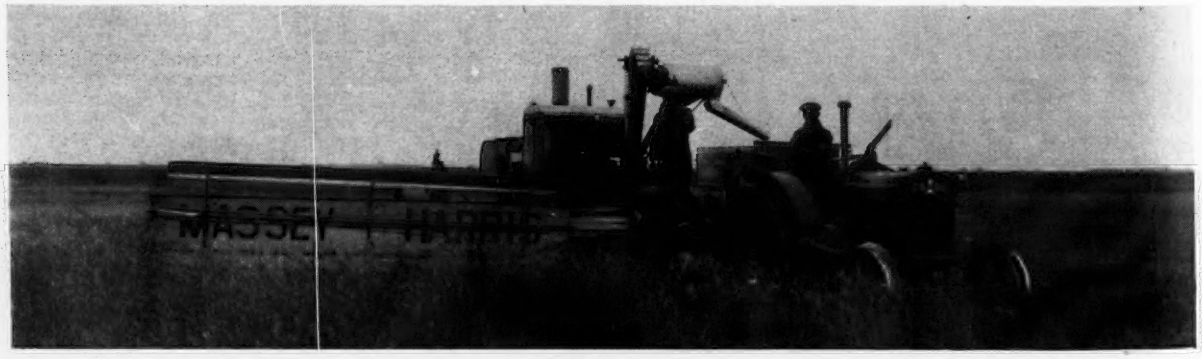

In 1924 Illinois used its first combine; in 1925 it used twelve, and in 1926 between sixty and seventy

better than the tooth cylinder, because the bar cylinder does not mash as many bull nettle berries.

The biggest loss in harvesting soybeans with the combine occurs back of the cutter bar. The amount of the loss depends on the amount of lodging, the height of cut, and the height of the lowest pods on the stems. On level ground the combine, if properly adjusted, was able to cut as low as four inches above the ground. To do this it was necessary in some cases to use a special low-cutting type of cutter bar and use special shoes at each end of the cutter bar, and then adjust the cutter bar so that the special shoes acted as runners and prevented the guards from running into the ground. That change is necessary if the cutter bar is to run as low as possible at all times. Lodged beans, even if they were leaning in the direction of travel, were picked up quite satisfactorily when the forward motion of the combine was slowed down, permitting the reel slats to move faster than the forward travel of the machine, as then the reel picks up the stalks and puts them back on the platform.

Manchu beans, which are grown to a large extent in Illinois, will average about 140,000 beans per bushel. A loss of three beans per square foot means a loss of one bushel per acre. If there are one or two pods left on the stalk the loss soon runs very high.

In the case of wheat and oats probably the greatest advantage in the use of the combine is the saving in the cost of putting the crop into the bins, and not so much in the saving of grain, although our results show a difference of three per cent in favor of the combine, in wheat. Efficiency tests have not been made in oats. In wheat the loss back of the cutter bar was about the same as that from the threshing and separating parts of the machine. The loss from the threshing and separating parts of the combine was due to improper adjustments or overloading. However, the combine cannot be expected to do as efficient a job of threshing as a stationary thresher.

Weeds and sweet clover caused considerable difficulty in harvesting one field of spring wheat last summer. The sweet clover was sown with the spring wheat and made an exceptionally rapid growth, while the wheat did not do very well. At the time of harvesting, which was rather late, the sweet clover in many places was almost as tall as the wheat. The large amount of very green material going through the machine made the grain somewhat moist, and made it necessary to clean the sieves rather frequently. A condition like that is abnormal, but nevertheless may be encountered once in a while.

Sweet clover is another crop that has caused considerable grief in harvesting. The combine has been used quite successfully in harvesting sweet clover and at the present time furnishes the best method of harvesting that crop. Due to the smallness of the seeds, and the shattering, no accurate methods of determining the loss in harvesting sweet clover have been devised. The loss by the combine has been estimated as low as 10 per cent in some cases, but no doubt the average loss would run somewhat higher. The sweet clover crop is a difficult crop to harvest, and for this crop the combine has its difficulties. It is almost necessary to have an extra man ride the platform to help feed the material into the machine, the ripe plants being so bushy and light that the platform canvas has difficulty in carrying them to the feeder.

Combines that receive their power from separate power units and those that are driven through a power take-off from the tractor have been used in harvesting sweet clover. The combines with the separate power unit have a decided advantage in harvesting sweet clover, because of the tendency of the machine to clog due to the large amount of material going through. In the case of the power take-off machines it is necessary when they start to choke, to stop the whole machine to stop the forward motion of the outfit. Then the cylinder is stopped with a large bunch going in and it is impossible to start the machine again until the cylinder has been cleared, and it is necessary to turn the cylinder backward by hand to do it. If the combine has a separate power unit, the forward motion can be regulated to suit the condition. The same thing could be accomplished in the case of the power take-off by independent drive ahead of the regular tractor clutch. However, that probably would mean some expensive changes in the design of most present day tractors. Under some conditions the tractor with the power take-off is overloaded.

Red clover and alsike clover may be harvested with the combine if there is no green material. One farmer decided that there was too much green material in his clover to do a successful job of cutting and threshing in one operation so he cut it with the mower, let it cure in the windrow and then used a cylinder-type hay loader to get the clover on the platform of the combine. The combination worked out well but required more time than if both the cutting and threshing had been done in one operation.

Statements from combine owners in Illinois show that they are very well satisfied with the performance of the combine and are enthusiastic about its possibilities. There has been a number of objections advanced as to why the combine would not prove successful in Illinois. It is interesting to note that the objections do not come from those who have used the combine. Up to the last few years it has been taken for granted that the combine was confined to arid and semi-arid regions and where farming is done on a much larger scale than it is in Illinois. However, moisture determinations show that the grain harvested with the combine has as low a moisture content, and in many cases lower, than the grain harvested by the ordinary method, and no emphasis need be placed on artificial drying of the grain harvested with a combine in Illinois.

Small fields are also advanced as an objection to the general use of the combine. The small combine is able to work in small fields almost equally as well as the binder, and with folding cutter bars, bridges and gates of reasonable width do not cause any difficulty in moving between fields. The manufacturers have met the objection that the farmer wants to save the straw by putting bunching attachments on the combine. That equipment makes it possible to save the straw with very little extra expense.

The hazard of losing the crop during the period between the time of cutting with a binder and the time of harvesting with a combine, which is usually from seven to ten days, has been emphasized too much. Weeds cause some trouble, but it is only in abnormal cases that they cause any difficulty of consequence. Most farms already are equipped with harvesting machinery, and many with threshing equipment, and an investment in a combine would mean duplication. This would seem like a reasonable objection, if it were not for the fact that the combine brings about such a big saving in the cost of harvesting and saving of grain. In spite of all the objections that have been made by nonowners the sale of combines has not been seriously handicapped and the owners of the combines are going ahead and harvesting their crops, while many of their neighbors are losing a large part or all of their crops in harvesting them by the ordinary method.

## Short Courses at Saskatchewan

THE department of agricultural engineering at the University of Saskatchewan has just completed three of its winter short courses, as reported by E. A. Hardy. In Saskatchewan all operators of steam engines must be licensed and the department conducts a steam engineering short course designed to assist the operator in preparing for the provincial examination.

In the January gas engine short course there were in attendance eighty-six farmers from the province, the course covering a detailed study of the stationary engine, the automobile and the tractor engine.

The threshing machine short course was well attended by sixty-four Saskatchewan farmers who spent a week in the study of threshing machines and the combined harvester-thresher. A great amount of interest was shown in the adjustments of the grain separator and the possible use of the combine.

The fourth and last course, on the gasoline engine, was started early in February with an attendance of approximately sixty.

# Research in Agricultural Engineering

A department conducted by the Research Committee of the American Society of Agricultural Engineers

## Kinematics and Dynamics of the Wheel Type Farm Tractor*

### IV. Dynamics—Turning Moments of External Forces

By E. G. McKibben[1]

THE stability of a tractor and the relative magnitudes of the supporting soil reactions against the front and the rear wheels (See $R_3$ and $R_5$, Fig. 15) are controlled by the magnitude and direction of the turning moments of the external forces. Since the stability of a tractor determines the safety of its operator, and the magnitudes of the supporting soil reactions against the front and rear wheels determine its steering and tractive abilities, the turning moments of the various external forces are of vital importance to the tractor designer, student and operator.

In Fig. 15 are shown the forces which were discussed in detail in the preceding article of this series. In considering the turning moments resulting from these forces any axis parallel to the rear axle may be assumed. However, it is most convenient to assume an axis through C, that is, the intersection of the resultant, $R_1$, of the tractive soil reactions against the drivewheels (either front or rear) and the resultant, $R_2$, of the supporting soil reactions against the rear wheels. This is due to the following facts: First, under almost all conditions all the forces acting upon a tractor can be resolved into couples; second, except for the supporting soil reaction against the front wheels, one of the forces forming each of these couples passes through this axis; third, the other force of each of these couples times the perpendicular distance of its line of action from the axis through C is a measure of the turning moment of the couple.

Thus considering the moments about an axis through C parallel to the rear axle (See Fig. 15), the following moments result:

1. $Wx_2$, due to weight of entire tractor
2. $R_3d_7$, due to downward soil reactions against the drivewheels
3. $R_4d_8$, due to rolling resistance of rear wheels
4. $R_5d_9$, due to supporting soil reaction against front wheels
5. $R_6d_{10}$, due to rolling resistance of front wheels
6. $P_ox_o$ or $P_hx_1$, due to the load resistance. (If $P_o$ is considered as acting at B', $P_hx_1$ may be substituted for $P_ox_o$. Since $P_h$ bears as close a relation to the tractive ability and the engine torque as $P_o$, and since $P_h$ is more nearly a measure of the useful work done than $P_o$, $P_h$ and $x_1$ will be used in this discussion rather than $P_o$ and $x_o$). It should be noted that $P_h = P_o \cos \beta_3$ and that $x_1 = \frac{x_o}{\cos \beta_3}$

*Fourth of a series of seven articles. The first installment appeared in the January issue. The fifth article of the series, entitled "Dynamics—Stability," will appear in the May issue of AGRICULTURAL ENGINEERING. The material presented in these articles was obtained as the result of an agricultural engineering project of the Agricultural Experiment Station of the University of California. It has been edited and approved by the Research Committee of the American Society of Agricultural Engineers.

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**Notation of Fig. 16**

- $\beta_1$, angle between line parallel to wheel base and $d_2$
- $\beta_2$, angle between line parallel to wheel base and $d_4$ extended
- $\beta_3$, angle between line parallel to the direction of motion of the center of the rear axle and the line of action of the load resistance, when the wheel base is parallel to the direction of motion of the center of the rear axle
- $d_1$, perpendicular distance from H to line through C parallel to the direction of motion of the center of the rear axle
- $d_2$, distance from H to B
- $d_3$, perpendicular distance from O to line through C parallel to direction of motion of center of rear axle
- $d_4$, distance from B to O
- $d_5$, difference between $d_2$ and $d_1$, that is, $d_5 = d_2 - d_1$
- $d_6$, distance from O to G
- k, distance between lines through O and C perpendicular to the direction of motion of the center of the rear axle
- $x_1$, moment arm of $P_h$ (See Fig. 15)
- $x_2$, moment arm of weight of tractor (See Fig. 15)
- $y_1$, angle between horizontal and direction of motion of the center of the rear axle
- $z_1$, angle between the direction of motion of the center of the rear axle and the wheel base
- $z_2$, change, due to angle $z_1$, in angle between direction of motion of the center of the rear axle and the line of action of the load resistance
- B, point of hitching to rigid frame of tractor
- B', point of intersection of line HB with line through C perpendicular to the direction of motion of the center of the rear axle
- C, intersection of the resultants of the tractive and supporting soil reactions against the drivewheels
- $CC_h$, horizontal line through C
- $CC_p$, line through C parallel to the direction of motion of the center of the rear axle
- $CC_v$, vertical line through C
- D, center of the front wheel
- G, location of center of gravity
- H, point of hitching to rigid frame of implement
- HH', line through H parallel to direction of motion of the center of the rear axle
- O, center of the rear wheels
- O', intersection of line through O perpendicular to the direction of motion of O, with a line through B, parallel to the direction of motion of O

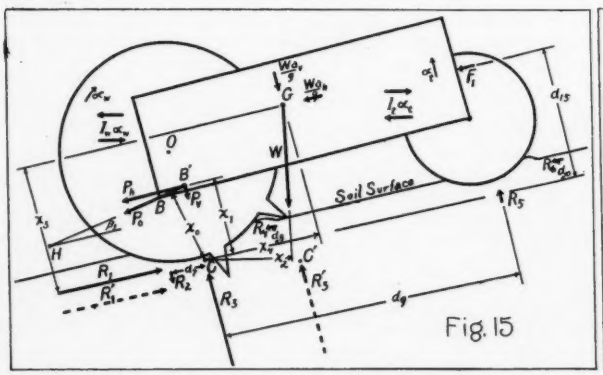


Fig. 15

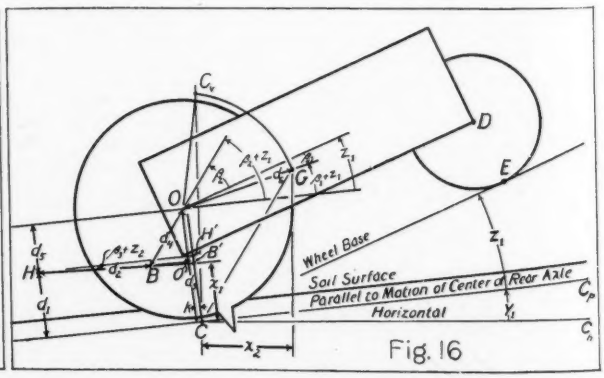


Fig. 16

7. $\frac{Wa_hx_3}{g}$, due to acceleration of the center of gravity, G, parallel to the direction of motion of the center of the rear axle
8. $\frac{Wa_vx_4}{g}$, due to acceleration of the center of gravity, G, perpendicular to the plane of motion of the center of the rear axle
9. $I_t \propto_t$, due to angular acceleration of the entire tractor with respect to the earth
10. $I_w \propto_w$, due to angular acceleration of the drivewheels with respect to the frame of the tractor
11. $F_1d_{15}$, due to wind resistance

Since the algebraic summation of all moments parallel to a given plane must equal zero, for the situation shown in Fig. 15,

$$Wx_2 - R_2d_7 - R_4d_8 - R_5d_9 - R_6d_{10} - P_hx_1 - \frac{Wa_hx_3}{g} + \frac{Wa_vx_4}{g} + I_t \propto_t - I_w \propto_w - F_1d_{15} = 0 \quad (10)$$

**Unknown Factors.** As stated in the preceding article the exact location of C under many operating conditions is not known but depends upon the tractor, soil, load, and speed. Therefore, even for a given tractor on a so-called uniform soil the location of C is constantly changing. Thus the lengths of all moment arms are also constantly changing within the limits resulting from the extreme limiting positions of C. While it would undoubtedly seldom happen, it would be possible under certain nonuniform soil conditions for $R_1$, $R_3$, and C to have the positions indicated as $R'_1$, $R'_3$, and C' of Fig. 15. This indicates that in designing a tractor consideration should be given to the probable effect of the most unfavorable of the possible locations of C.

**Known Factors.** On the other hand, there are many adjustments and operating condition changes the effect of which can be definitely predicted. Some of the more important are the location of the point of hitch to the tractor, location of the point of hitch to the implement, length of hitch, grade, and location of the center of gravity. The effect of these changes on the length of the moment arms is a measure of their effect upon the behavior of the tractor. Therefore, their effect upon the length of the important moment arms forms a logical basis for the discussion of these adjustments and operating condition changes.

**Moment Arm of Component of Load Resistance Parallel to the Direction of Motion of the Rear Axle ($x_1$).** As will be shown in a later article the length of $x_1$ (See Figs. 15 and 16) is of great importance in connection with the stability and tractive ability of a tractor. Using the notation of Fig. 16, the following equations may be derived for $x_1$. (This is of course assuming that the lengths of $d_3$ and k remain constant, that is, that the relative position of C remains unchanged.)

$$x_1 = d_3 - d_4 \sin(\beta_2 + z_1) + [d_4 \cos(\beta_2 + z_1) + k] \tan(\beta_3 + z_2) \quad (11)$$

The value of $\tan(\beta_3 + z_2)$ in terms of $(\beta_2 + z_1)$ is

$$\tan(\beta_3 + z_2) = \frac{d_5 - d_4 \sin(\beta_2 + z_1)}{\sqrt{d^2_2 - [d_5 - d_4 \sin(\beta_2 + z_1)]^2}}$$

Substituting this value for $\tan(\beta_3 + z_2)$ in Equation 11,

$$x_1 = d_3 - d_4 \sin(\beta_2 + z_1) + \left\{ \frac{[d_5 - d_4 \sin(\beta_2 + z_1)][d_4 \cos(\beta_2 + z_1) + k]}{\sqrt{d^2_2 - [d_5 - d_4 \sin(\beta_2 + z_1)]^2}} \right\} \quad (12)$$

Thus for a given tractor with a given hitch, Equation 12 gives the value of $x_1$ in terms of constants and one variable, $z_1$, for any position of the tractor. The value of $x_1$ for a specific situation may be obtained either by substituting the proper numerical values in Equation 12, or graphically by making a large scale drawing of the drawbar and implement hitch situation.

If $z_1$ is equal to zero, that is, with the wheel base parallel to the plane of motion of the rear axle, Equation 11 will become

$$x_1 = d_3 - d_4 \sin\beta_2 + \tan\beta_3 (d_4 \cos\beta_2 + k) \quad (13)$$

The effect of variations of $\beta_2$, $\beta_3$, $d_1$, $d_2$, $d_4$, $d_5$, or $z_1$ on the value of $x_1$ is most easily shown by determining a few values of $x_1$ and plotting curves as shown in Fig. 17.

In the following discussion of $x_1$, only values of $\beta_2$, from zero to +90°, of $\beta_3$ from —90° to +90°, of $z_1$ from zero to +90°, of $d_3$ equal to or greater than $d_5$ and equal to or greater than the difference between $d_4$ and $d_5$ are considered. It is also assumed that within these limits there will be no interference between the hitch and the tractor frame thus causing a change in the effective location of point B.

Under these limitations $x_1$ has the following relationship to the constants of Equation 12 (See Fig. 16.):

1. Length of $d_1$
   (a) When B is on line B'C, the length of $d_1$ has no effect upon $x_1$
   (b) When B is back of line B'C, increasing $d_1$ decreases $x_1$
   (c) When B is in front of line B'C, increasing $d_1$ increases $x_1$
2. Length of $d_2$
   (a) When B is on line B'C, the length of $d_2$ has no effect upon $x_1$
   (b) When B is on line HH', the length of $d_2$ has no effect upon $x_1$
   (c) When B is below HH' and back of B'C, or above HH' and in front of B'C, increasing $d_2$ increases $x_1$
   (d) When B is above HH' and back of B'C, or below HH' and in front of B'C, increasing $d_2$ decreases $x_1$
3. Length of $d_3$
   (a) When H is back of line B'C, increasing $d_3$ will increase $x_1$
   (b) When H is in front of line B'C, increasing $d_3$ will decrease $x_1$
4. Length of $d_1$ and $d_2$
   (a) If $d_1$ and $d_2$ are increased equally, $x_1$ is increased an equal amount
5. Length of $d_4$
   (a) If H is back of line B'C, and B is below the line through O perpendicular to B'C, increasing $d_4$ will decrease $x_1$
6. Length of $d_4 \sin(\beta_2 + z_1)$, that is, OO'
   (a) When H is back of line B'C, increasing OO' decreases $x_1$
   (b) When H is in front of line B'C, increasing OO' increases $x_1$
   (c) When OO' becomes greater than $d_3$, B will strike the soil and prevent further increase of angle $(\beta_2 + z_1)$
7. Length of $d_4 \cos(\beta_2 + z_1)$, that is, BO'
   (a) When B is on line HH', that is, when $\beta_3$ is zero, the length of BO' has no effect on $x_1$
   (b) When B is above line HH', that is, when $\beta_3$ is positive, increasing BO' increases $x_1$
   (c) When B is below line HH', that is, when $\beta_3$ is negative, increasing BO' decreases $x_1$
8. Algebraic value of k
   (a) Changing the algebraic value of k changes the value of $x_1$ an amount equal to the tangent of $(\beta_3 + z_2)$ times the changes in k
   (b) If B is on line HH', that is, if angle $(\beta_3 + z_2)$ is equal to zero, changing k will have no effect on $x_1$
   (c) If B is above HH', that is, if angle $(\beta_3 + z_2)$ is positive, increasing k will increase $x_1$
   (d) If B is below HH', that is, if angle $(\beta_3 + z_2)$ is negative, increasing k will decrease $x_1$

In Fig. 17 the length of $x_1$ in inches is plotted against the magnitude of $z_1$ in degrees, for eight different drawbar hitch situations. The values of $x_1$ were obtained by making large scale drawings of the drawbar hitch situation for each ten-degree value of $z_1$. The table in Fig. 17 completely defines each of these eight drawbar hitch situations; also situation No. 1 is shown in Fig. 16. In No. 2 the hitch is lengthened, that is, $d_2$ is lengthened 6 inches. In No. 3 the tractor hitch point is moved backward approximately 9 inches. In No. 4 the tractor hitch point is moved backward approximately 13.3 inches. In No. 5 the implement hitch point is lowered 2 inches. In No. 6 the hitch point of the implement is raised 6 inches. In No. 7 the hitch point of the tractor is raised 4 inches and the hitch point of the implement is raised 2 inches. In No. 8 the assumed length of k is increased 5 inches.

In order to check Equation 12 several of the values of $x_1$ were determined mathematically by substituting in Equation 12. The results were found to check within the limits of plotting and measuring, for example, if the constants for $z_1$ equal to 20 degrees and drawbar situation No. 6 are substituted in Equation 12.

$$x_1 = 24 - (18)(.807) + \frac{[4 - (18)(.807)]\,[(18)(.5906) + 1]}{\sqrt{(24)^2 - [4 - (18)(.807)]^2}}$$

Simplifying, $x_1 = 3.79$ inches

Solution by the graphical method where the drawbar hitch layout was drawn to a half size scale gave,

$x_1 = 3.80$ inches

From these curves it is possible to obtain the value of $x_1$ for any one of the given drawbar situations and any value of $z_1$ up to 90 degrees. On Fig. 17 both the negative and positive values of $x_1$ are shown. However, unless some moment besides the load resistance moment, $P_h x_1$, were tending to overturn the tractor, the tractor would cease to rise before $x_1$ becomes negative.

Also, in case $d_4$ is greater than $d_3$ the tractor cannot rise (that is, $z_1$ increase) much beyond the point where $d_4 \sin(\beta_3 + z_1) = d_3$, for at this point B will begin to support the weight of the rear end of the tractor decreasing $R_2$ acting at C, thus decreasing the tractive ability of the drivewheels. Therefore, the values of $x_1$ obtained after $d_4 \sin(\beta_2 + z_1) = d_3$ are plotted as broken lines in Fig. 17.

By the use of this type of curve it is also possible to visualize the effect of altering the drawbar hitch situation upon the length of $x_1$ and upon the rate of change of $x_1$ as angle $z_1$ increases. Probably the most important fact brought out by the curves in Fig. 17 is the stabilizing effect of lowering the point of hitch to the tractor (B of Fig. 16) or moving it back from the rear axle. (Note Curves 3 and 4.) Curve 7 shows the opposite effect produced as a result of raising the tractor hitch point and moving it forward. If there is any probability of the tractor becoming unstable, the matter of possible locations of the tractor hitch point, B, should be given careful consideration by the designer. Under certain circumstances it may be a matter of life and death to the operator.

**Moment Arm of Weight of Tractor ($x_2$).** So far as the behavior of a tractor is concerned, the value of $x_2$ is probably of greater importance than that of any other moment arm.

For a given tractor with $z_1 = 0$ and $y_1 = 0$, that is, with the plane of motion of the rear axle horizontal and the wheel base horizontal,

$x_2 = d_6 \cos \beta_1 - k$ (See Fig. 16) .....(14)

As soon as $y_1$ appears, that is, as soon as the plane of motion of the center of the rear axle ceases to be horizontal,

$x_2 = d_6 \cos(\beta_1 + y_1) - d_3 \sin y_1 - k \cos y_1$ .....(15)

If the front of the tractor rises while on level ground, that is, if the wheel base ceases to be parallel to the plane of motion of the center of the rear axle while that plane is horizontal, $z_1$ is introduced and Equation 14 becomes

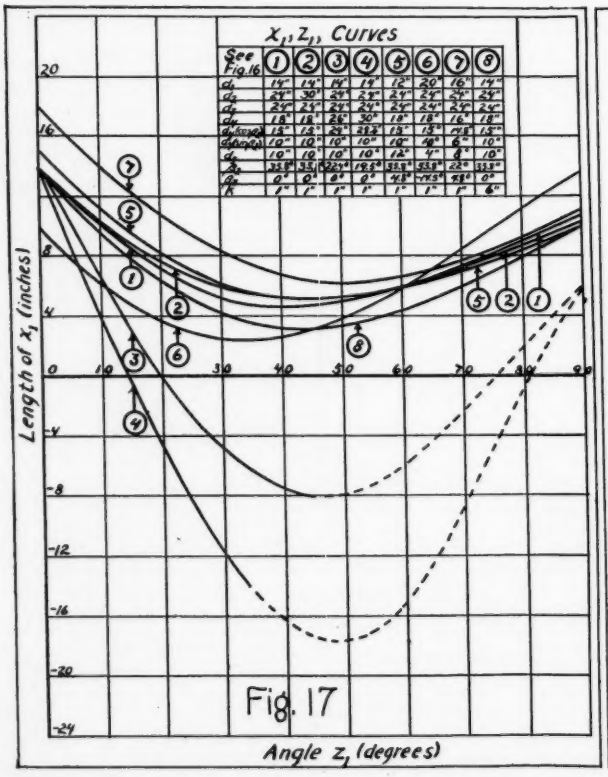
$x_2 = d_6 \cos(\beta_1 + z_1) - k$ .....(16)

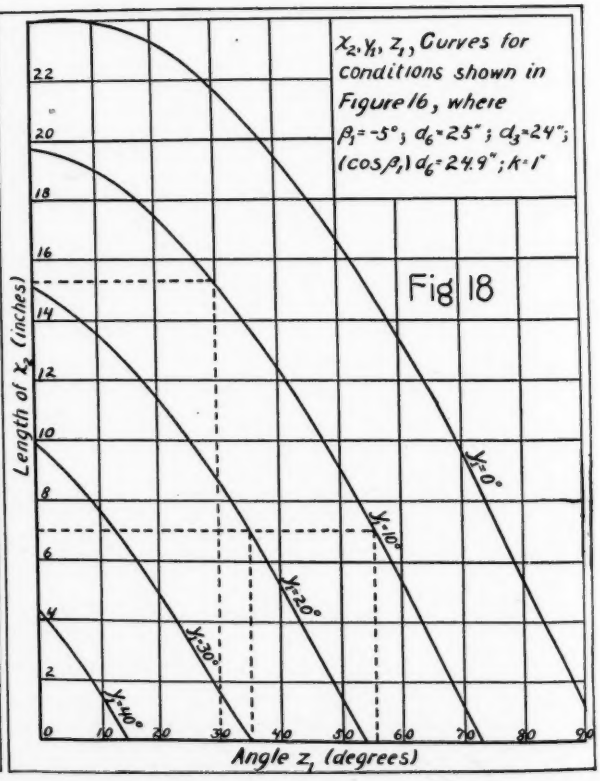
If both $y_1$ and $z_1$ are present Equation 14 becomes

$x_2 = d_6 \cos(\beta_1 + y_1 + z_1) - d_3 \sin y_1 - k \cos y_1$ .....(17)

The above equations indicate the following:

1. Increasing $d_6$ increases $x_2$ for all positions of the tractor except where angle $(\beta_1 + y_1 + z_1) = \pm 90°$ (See Equation 17)
2. Increasing $d_3$ increases the effect of angle $y_1$ and therefore the disturbing effect of grades (See Equations 15 and 17)
3. Increasing $d_5$ has no effect upon the results produced by $z_1$ (See Equation 16)
4. On level ground, if the front wheels start to rise, $x_2$ will be maximum when $(\beta_1 + z_1) = 0$, and will decrease as $(\beta_1 + z_1)$ increases from zero to +180, the rate of decrease being greatest when $(\beta_1 + z_1) = +90°$, and least when $(\beta_1 + z_1) = 0$
5. On level ground with the front wheels on the ground, if $\beta_1$ is varied, $x_2$ will be maximum when $\beta_1$ is equal to zero
6. On a grade the effect of varying $z_1$ will be the same as above, except $(\beta_1 + y_1 + z_1)$ should be substituted for $(\beta_1 + z_1)$
7. Increasing the value of k decreases the value of $x_2$ by the cosine of $y_1$ times the increase of k
8. On level ground Equation 14 indicates that $x_2$ will become zero when $d_6 \cos(\beta_1 + z_1) - k = 0$, or $d_6 \cos(\beta_1 + z_1) = k$ .....(18)





$x_2, y_1, z_1$, Curves for conditions shown in Figure 16, where
$\beta_1 = -5°$; $d_6 = 25"$; $d_3 = 24"$;
$(\cos \beta_1)\, d_6 = 24.9"$; $k = 1"$
Length of $x_2$ (inches)
Angle $z_1$ (degrees)
$y_1 = 0°$
$y_1 = 10°$
$y_1 = 20°$
$y_1 = 30°$
$y_1 = 40°$
Fig 18

9. On a grade Equation 17 indicates that $x_2$ will become zero when

$$d_6 \cos(\beta_1+y_1+z_1) - d_3 \sin y_1 - k \cos y_1 = 0, \text{ or}$$
$$d_6 \cos(\beta_1+y_1+z_1) = d_3 \sin y_1 + k \cos y_1 \quad \ldots\ldots\ldots (19)$$

If angle $C_hCC_p$ equals a given value of $y_1$, then angle $GOC_v$ equals the increase in value of $z_1$ required to make $x_2$ equal to zero, or if angle $C_pCE$ equals the value of $z_1$, then $GCC_v$ equals the increase in the value of $y_1$ required to make $x_2$ equal zero.

For the center of gravity location shown in Fig. 16 and defined on Fig. 18, the value of $x_2$ for each ten-degree change in $z_1$, for each ten-degree change in $y_1$ was determined graphically by making a large drawing to scale, and scaling off the lengths $x_2$. The changes in $y_1$ and $z_1$ were carried to the point where $x_2$ becomes zero. If $y_1$ or $z_1$ is increased beyond this point, the tractor will continue to turn over due to the moment $Wx_2$ without the aid of any other disturbing moment. The data thus obtained was used to plot the curves of Fig. 18. From these curves it is possible to obtain for the center of gravity location under consideration the value of $x_2$ corresponding to any given value of $y_1$ and $z_1$, or the value of $y_1$ corresponding to any given values of $x_2$ and $z_1$, or the value of $z_1$ corresponding to any given values of $x_2$ and $y_1$. Thus,

if $y_1 = 10°$ and $z_1 = 30$, then $x_2 = 15.3°$; or

if $x_2 = 7$ and $z_1 = 35°$, then $y_1 = 20°$; or

if $x_2 = 7$ and $y_1 = 10°$, then $z_1 = 55.8°$.

Of course, if these curves were to be used in actual design, they should be plotted on a larger scale, thus increasing their accuracy. It should also be noted this set of curves defines the situation for only one location of C. If a study of a specific tractor were being made several sets of curves similar to Fig. 18 should be plotted, using a different location of C for each set. Thus it would be possible to illustrate graphically the effect of the magnitudes of $y_1$ and $z_1$ and the location of C upon the length of the moment arm, $x_2$.

In order to check Equation 17 several of the values of $x_2$ were determined mathematically by substitution in Equation 17. The values thus obtained agreed with those obtained graphically within the limits of plotting and measuring. For example, if the constants for the center of gravity location under consideration and for $y_1 = 10°$ and $z_1 = 20°$ are substituted in Equation 17,

$$x_2 = (25)(.9063) - 24(.1736) - 1(.9848)$$
$$= 17.51 \text{ inches},$$

and when obtained graphically $x_2 = 17.48$ inches

**Moment Arms $x_3$ and $x_4$ of Inertia Forces $\frac{Wa_h}{g}$ and $\frac{Wa_v}{g}$.**

Using the notation of Fig. 16 the following equations may be derived for $x_3$ and $x_4$

$$x_3 = d_3 + d_6 \sin(\beta_1+z_1) \quad \ldots\ldots\ldots (20)$$
$$x_4 = d_6 \cos(\beta_1+z_1) - k \quad \ldots\ldots\ldots (21)$$

**General Moment Equation.** If the values of $x_1$, $x_2$, $x_3$ and $x_4$ given in Equations 12, 17, 20, and 21, respectively, are substituted in Equation 10, this equation becomes a general moment equation for any position of the tractor. This moment Equation 10 and the two force Equations 8 and 9, which were developed in the preceding article, constitute the proper basis for a careful study of the utility of a tractor, that is, its probable stability and tractive and steering ability.

(The fifth article of this series will appear in the May issue.)

# The Ahart System of Growing Corn*

By J. B. Davidson[1]

THE largest and most important contribution to the growing of corn that has been made in the Middle West is the pointing out of the necessity of including a legume in the crop rotation; in most conditions sweet clover fits in. If we are going to grow corn profitably and get the yields we should, we must have a crop rotation plan that includes a legume.

The simplest form of crop rotation plan that can be practiced is a three-year plan. It can be expanded into four and five years, depending on the amount of livestock kept. Oats and sweet clover are seeded together. The clover is allowed to grow in the fall after the oats are harvested and the next spring for green manure. Then it is turned under and the corn planted. This is followed again with corn, and then the oats and sweet clover. The practice of that rotation has far more influence upon crop yields than anything else that has been proposed.

With a short season like we have in this section of the country, if the sweet clover is allowed to grow long enough to produce a good green manure crop, it calls for a peak load of power just at the last moment when getting ready to plant corn. To avoid this peak, J. Leo Ahart, of Crawford County, Iowa, in his system of corn growing, allows his sweet clover to grow in the spring until it has a good growth. Then with his three-plow tractor he turns it under, using a 12-inch plow with a 14-inch plowshare, so he gets all the roots. He also uses a packer behind the plow, which he has found quite essential. Then if it doesn't rain he packs the ground the second time right away, because if the soil it not packed in late plowing the yield is reduced rather than increased. It was discovered in this connection that plowing can be done very late provided the soil is put into the right condition.

Mr. Ahart uses a harrow once before the corn comes up and once after it comes up, using thirty feet of harrow and covering eight rows at a time. Then he goes over his corn twice with a spring-tooth (Forkner) harrow, with one tooth removed, which covers four rows at a time. Then he cultivates his corn but once. His yield is about sixty bushels to the acre on the average, while the average for the state is about forty bushels.

What is he accomplishing so far as man labor is concerned? Some years he has the cornstalks to take care of. That depends on whether he is following oats or corn. He breaks down and rakes up and burns the stalks to get rid of them. He says they are no good so far as he is concerned. I don't know how much time this takes; I suppose about 0.2 hours per acre. He is able to plow an acre with a section of soil packer behind the plow and a section of harrow behind that in about 0.9 hours. Then going over the ground once or twice with a heavily weighted packer and harrow, he uses from 0.4 to 0.8 hours in preparing the seedbed. Planting the corn takes 0.5 hours per acre. He goes over it twice with the smoothing harrow, taking 0.25 hours, 0.125 hours for each time over. Then he goes over it twice with the Forkner harrow, taking 0.25 hours for each time over, or 0.5 hours for twice over. Finally he goes over it once with a two-row cultivator, taking 0.5 hours for an acre. Providing for some overhead to cover losses, as in selecting seed corn, adding all these together shows that he is producing an acre of corn—up to the time of harvesting and following the best program for corn production that we know—at an expenditure of four man-hours per acre.

Mr. Ahart harvests nearly all his crop with livestock. He hasn't found it advantageous to buy mechanical pickers. As the amount of picking is small he hires it done by the bushel. If Mr. Ahart would husk the corn by hand it would take five hours, and with the mechanical picker about two and a half hours.

The interesting thing about all this is that is carrying into practice the best agricultural program we have. Mr. Ahart doesn't believe in selling any grain off his farm. He is producing something more than 4,000 pounds of meat per acre on his farm. He can use a harrow, because he doesn't have a soil that forms a crust. With a soil that forms a crust, of course, the harrow may not be the thing to use. An additional advantage of this method is that the late plowing reduces weed troubles.

*Presented at a meeting of the Farm Power and Machinery Division of the American Society of Agricultural Engineers, at Chicago, December 1 and 2, 1926. Abridged.

[1]Professor of agricultural engineering, Iowa State College. Charter, A.S.A.E.

# News of the Annual Meeting

**University Farm, St. Paul, Minn.—June 22-25, 1927**

## A. S. A. E. Annual Meeting Offers Excellent Program

CONCEDED to be the premier event in agricultural engineering circles, the annual meeting of the American Society of Agricultural Engineers will be held this year June 22 to 25 at University Farm, St. Paul, Minnesota. While not apparent on the surface, changes of tremendous importance and significance to the agricultural and allied industries are taking place. The agricultural industry has been slow to recognize the place which engineering holds in agricultural development and to accept the findings and recommendations of agricultural engineers who seek to do for agriculture what engineering has already accomplished in the manufacturing industries and transportation.

A fundamental change, however, is taking place. The past year has seen a great deal of progress in the direction of a more receptive attitude to what the engineer has to offer. As a matter of fact, the demands on the agricultural engineering profession right now are all out of proportion to its numbers.

The twenty-first annual meeting of the Society again presents the opportunity for members of the profession to meet and discuss individually and collectively their mutual problems, to renew old acquaintances and to make new ones. The meeting offers new inspiration and new vision, very essential to the professional man's progress and development.

In addition to providing the necessary facilities for the successful handling of the meeting, those in charge of local arrangements are providing for the maximum of comfort, convenience, and pleasure for members and guests. Special committees have been appointed—and their work is already well in hand—to take care of entertainment, housing, information service, ladies' entertainment, meetings arrangements, publicity, registration, student branch affairs, and transportation.

Most of the sessions of the meeting will be held in the Agricultural Engineering Building at University Farm, at which is located the college of agriculture of the University of Minnesota.

The program will be a well-balanced combination of general papers and addresses, technical papers, business, committee reports, group meetings and conferences, and entertainment.

Reception and registration of A.S.A.E. members and others attending the meeting will begin at 8:30 A.M. of the first day, Wednesday, June 22. At 9:30 the programs of the Rural Electric and Reclamation Divisions will open and occupy the remainder of the morning and afternoon. These sessions will feature committee reports, discussion of plans for the coming year, and the presentation of technical papers.

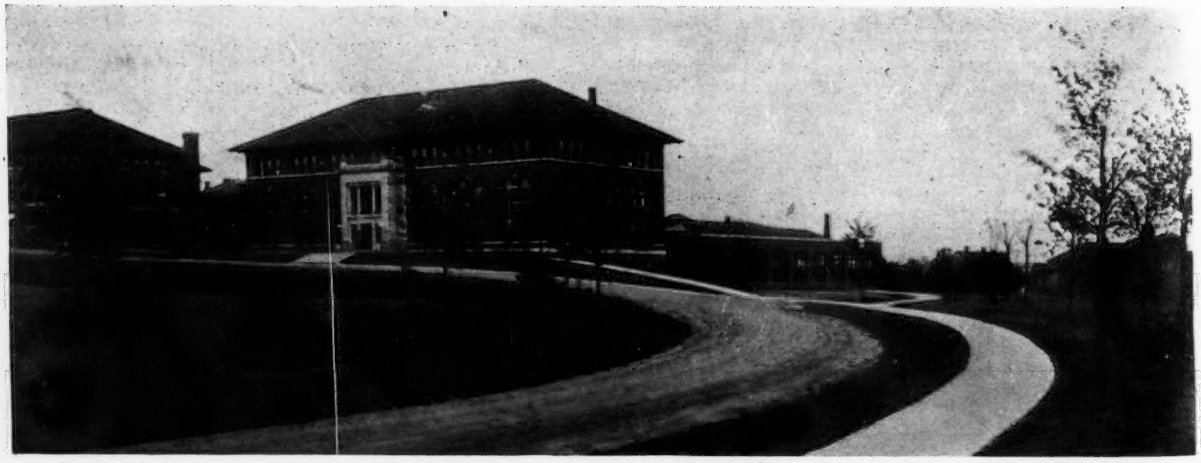
The rural electrification program will include papers on rural electrification in Europe, some phase of the rate question, rural refrigeration, automatic feed grinding, and activities of the public utilities interests in advancing the use of electricity in agriculture.

For the morning program of the reclamation session several committee reports have been scheduled, including drainage in humid regions, drainage of irrigated lands, erosion, forestry, land clearing, irrigation, land development and settlement, run-off from agricultural lands, and soil hydraulics. In the afternoon the reclamation program will feature technical papers on subsoil as a factor in drainage; silting of drainage ditches, including its control and prevention, and influence of growth on flow in open ditches.

From 6:30 to 7:30 P.M. of the first day a picnic supper will be held at University Farm, featuring Minnesota strawberries and cream. At that time the Minnesota Student Branch of the Society will entertain with a stunt.

Group meetings and conferences will be held from 8:00 P.M. on, during the evening of the first day. Those already scheduled for that time include meetings of the heads of agricultural engineering departments at the state colleges and universities, land clearing specialists, consulting agricultural engineers, and student members of the Society. Other groups wishing to hold meetings at the same time must make previous arrangement with the Meetings Committee.

The first general session of the meeting will open at 9:00 A.M. on the second day, June 23. Dean W. C. Coffey, of the Department of Agriculture, University of Minnesota, will de-



The Agricultural Engineering Building, University of Minnesota, where headquarters for the A.S.A.E. 1927 annual meeting will be located

liver the address of welcome, taking as his subject "Significant Changes Taking Place in Agriculture." This will be followed by the annual address of the president of the Society, O. W. Sjogren, which will complete the morning's program.

Continuing general session in the afternoon, Dean O. M. Leland, of the College of Engineering and Architecture, University of Minnesota, and president of the Society for the Promotion of Engineering Education, will address the meeting on training the professional agricultural engineer. A prominent agricultural engineer from abroad will address the meeting, probably on agricultural engineering development in Europe. One or two other addresses not scheduled at this writing will be delivered at this session.

Between 5:30 and 7:30 P.M. several special committee meetings and conferences will be called, and at 8:00 P.M. the annual business meeting of the Society will be called to order.

Continuing on the morning of the third day, June 24, the general session will feature the latest developments in agricultural engineering research. Next in order is to be an address by Thomas D. Campbell, president of the Campbell Farming Corporation, on "Handling the Labor Problem in Large Farming Operations." In addition one or more members of President Coolidge's Cabinet are expected to attend and address the Society at this session.

The afternoon of the third day will be given over to the programs of the Farm Structures and Farm Machinery Divisions. At 3:30 P.M. a trip to the experimental peat plots and the Bowman Farm buildings is scheduled.

The evening of June 24, commencing at 7:00 P.M., will be devoted to the A.S.A.E. annual banquet. The address of the evening will be delivered by Dean E. M. Freeman, of the College of Agriculture, University of Minnesota.

The entire fourth day, June 25, will be occupied by the program of the College Division.

The annual meeting program this year, more than ever before, is one which no agricultural engineer can afford to miss. If A.S.A.E. members thoroughly understood how much attendance at these meetings means to the promotion of the agricultural engineering profession and how the progress of the profession reflects back to them, improving their standing and advancement in the profession, every member would be at St. Paul, if humanly possible for him to be. The financial considerations involved in attending should be looked upon as an investment rather than as an expense. Presumably every member aspires to advancement in his profession or business. To advance, regardless of what position one may already hold, requires the expenditure of time, effort, and money, in addition to the minimum requirements of the position. The annual meeting is offered as an investment in professional advancement which will yield to members and to others interested who attend, both in direct and indirect returns, more than six per cent on as much time, effort, and money as they can see fit to invest.

# Local Committee Plans for Comfort and Enjoyment of Those Attending A.S.A.E. 21st Annual Meeting

THE convention headquarters during the twenty-first annual meeting of the American Society of Agricultural Engineers to be held at St. Paul, Minnesota, June 22 to 25, 1927, will be on the University Farm campus. The large Agricultural Engineering Building furnishes ample facilities for all meetings and conferences while the auditorium in the Administration Building with a seating capacity of approximately one thousand will be available for some of the general sessions and other special large gatherings.

The University Farm is located between Minneapolis and St. Paul, about five miles from the center of either city. The state fair grounds adjoin the University Farm campus on the east. The campus is about four blocks from Como Avenue where either street car or bus service may be obtained to either city about every ten minutes. Taxi service will also be available at University Farm for those who desire it.

The University Farm campus is quite large and is well supplied with trees, shrubs, and extensive lawns making it especially beautiful at that time of the year.

The campus has plenty of facilities for making the members and their families comfortable while attending the meeting. Between the gymnasium and the dormitories is a large area of lawn which is well shaded. This will be available for camping purposes and will be a splendid place for those who bring their tents and wish to live out-of-doors. The University Farm cafeteria will be in operation during the entire period of the meeting. The cafeteria prices are very reasonable and the quality of both food and service is good.

The headquarters office will be in the Agricultural Engineering Building. A room will also be provided especially for the ladies which may serve as a gathering and rest room. Arrangements have been made to have the college dormitories available for the members and their families. A charge of $1.00 per person per day will be made for dormitory accommodations. The rooms vary in size; thus single rooms may be obtained or a family may be conveniently grouped together. The dormitories are located near the cafeteria and very convenient to headquarters. One or more parlors in each of the buildings will make it convenient for groups or committees to congregate. Swimming pool and shower bath facilities in the gymnasium will be available at all times. Bathing beaches on nearby lakes may be readily reached from the campus.

Fine hotel accommodations may be obtained in either city at hotels easily and quickly accessible from University Farm for those who prefer such accommodations.

Golf or tennis may be indulged in by those who desire to do so. The campus has four tennis courts and the University golf course is located about one mile north of University Farm. Other golf courses are also readily accessible.

In general, the University Farm campus is a most delightful place to spend several days or a week. All members of the Society are urged to bring their wives and other members of their families. The twin cities and vicinity present many opportunities for pleasant pastime with their beautiful drives, parks, art galleries, lakes, amusements, etc. A special entertainment program is being provided for the ladies. This will be outlined in detail in the May issue of AGRICULTURAL ENGINEERING.

Several suggested tours have been outlined for those who are interested in spending some time in Minnesota after the meeting. These include tours of the agricultural sections of the state, the iron mines, the forests, the Arrowhead District, and some of Minnesota's famous ten thousand lakes. These tours will be outlined in detail in a later issue. Detailed information may also be obtained by those who would like to spend a vacation in Minnesota. Minnesota offers a large variety of vacation possibilities. The lake shores are dotted with beautiful hotels, lodges, cottages and camp grounds. Late June is the prime of the fishing season in northwestern Minnesota. The nonresident license fee is only $3.00.

The automobile roads leading to the twin cities from all directions afford the motorist ample opportunity to drive to the convention if he wishes to do so. Summer tourist railroad rates will be in effect in June from most points to St. Paul. Tentative plans include one or more special cars on the regular C. B. & Q. train leaving Chicago at 6:30 or 8:45 P.M., June 21, and reaching St. Paul at 7:00 or 8:15 the next morning.

For further information about the meeting write William Boss, Division of Agricultural Engineering, University Farm, St. Paul, Minnesota.

# AGRICULTURAL ENGINEERING

Established 1920

A journal devoted to the advancement of the theory and practice of engineering as applied to agriculture and of the allied arts and sciences. Published monthly by the American Society of Agricultural Engineers, under the direction of the Publications Committee.

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Contributions of interest and value, especially on new developments in the field of agricultural engineering, are invited for publication in this journal. Its columns are open for discussions on all phases of agricultural engineering. Communications on subjects of timely interest to agricultural engineers, or comments on the contents of this journal or the activities of the Society, are also welcome.

Original articles, papers, discussions, and reports may be reprinted from this publication, provided proper credit is given.

RAYMOND OLNEY, Editor


## Farm Home Research

IN ANY program of agricultural engineering research that research which relates to the farm home cannot be overlooked. Some preliminary studies that have already been made reveal the need for comprehensive and definite research to determine the factors involved in the planning of the farm home. That plans already in existence do not meet the need for farm homes is indicated by the statement in a paper presented at the last annual meeting, that from 54 to 68 per cent of the kitchen plans published are poor; apparently about two per cent may be classed as excellent; scarcely more than a fourth are good.

There is a wide divergence between the home as the farm woman would like to have it and actual conditions. In Mr. Brinckloe's report of his farm house contests, 98 per cent of the proposed plans had bathrooms; the size averaged 5.4 rooms per house; 40 per cent hardwood floors; 50 per cent fireplaces; 26 per cent electricity and sleeping porches. From 14 to 25 per cent wanted farm offices, sewing rooms, breakfast alcoves and pantries.

A study of 500 farm homes in Arkansas revealed an average size of between 4 and 5 rooms; 10 per cent with bathrooms; 9 per cent with running water; 6 per cent with indoor toilets. Twenty per cent had no toilet facilities at all. Seven per cent had electricity; 7 per cent sleeping porches. The only feature approaching the desires of the contest was the fireplace in 42 per cent of the homes. However, in the South the fireplace is used as a source of heat, and but one-half of one per cent had furnace heat.

Breakfast alcoves, sewing rooms, washrooms and offices were not found in as many as one per cent of the homes.

It is evident that there is a wide gap between what is desired and what may be had. Length of tenure, size of family, limitations of finance and a definite understanding of the needs must be considered in connection with any study of farm home planning.

Farm home research, either in plans or equipment offers an opportunity for the correlation of agricultural engineering with home economics. The research work approved within the past two years is notable for the increase in rural economics and home economics. Agricultural engineering fits well into many programs in both of these lines of work.

DEANE G. CARTER

## Engineering Must Be Sold

IN THE course of an editorial in "Engineers and Engineering," Herbert Hoover is quoted as having estimated that "while the number of wage earners in American factories increased 27 per cent in the last ten years, their output, in terms of quantity, increased nearly 60 per cent. Production per wage earner employed has advanced by at least 25 per cent."

Incidentally, that increase in productiveness may be compared with the estimate emanating from the Department of Agriculture to the effect that the production of the individual agricultural worker has increased 18 per cent over a materially longer period. As to cause, it may fairly be inferred that the relative increases in productive capacity are roughly proportional to the comparative employment of the engineer and the adoption of engineering methods. As to results, there is much reason to believe that the more rapid increase in productive efficiency in manufacturing has at least something to do with its more favorable economic position as contrasted with agriculture. The editorial states further:

"Increased production has come about very largely through the adaptation, by the engineer, of research in pure science to practical needs. How has this same knowledge—these new methods—reached the business man? In two important ways this new technique has spread to the industrial world.

"Where size and resources have permitted, business has set up its own laboratories and engaged its own staff of scientists and technicians. Or this knowledge has been secured through the medium of books, scientific journals, the reports of technical societies, and their publications.

"This latter is important for two reasons: First, every industry cannot maintain its own laboratory and staff of engineers. Secondly, a wide diffusion of knowledge is constantly necessary to avoid costly duplication of research and assure to industry as a whole the benefits of the latest and best scientific knowledge. . . . . .

"Yet despite the rapidity with which the engineer and his contributions have been utilized by industry and business, there exist today, unapplied and oftimes unknown, vast aggregations of technical knowledge. Engineers have asserted that technical knowledge is available which would go a long way toward the abolition of poverty, double or treble the standard of living, change ugly cities into noble ones, and by the means of electric power and decentralization bring the culture of the town to the countryside. . . . . .

"Much technical knowledge must, of course, remain unused for a considerable period of time, for its application would mean the scrapping of many large industrial units. Application must come about gradually. Yet, there is a danger that valuable technical knowledge which might be immediately useful will remain buried in brochures, locked in laboratory reports, or stand on shelves, unknown. Progress in industry rests not only upon the creation of new knowledge but also upon its diffusion."

## Drainage Results As A Tonic

THE returns from one's efforts often seem smaller than the energy expended. However, should you desire a certain glow of satisfaction that is more than equal to any salary check, just go look over some old drainage job and ask the farmer how he likes it. In checking up costs of the work, one farmer recently said, "The tile drainage has paid me better than anything I have ever had on the farm."

Not long ago a farmer put a drainage job under charge of his son just out of college, and the boy did the work according to the surveyor's figures. He had a system operating much better than one his father tried to construct without a survey. The boy is now more inclined to stay on the farm and see the results of the drainage.

If you want to make money for your clients and feel a certain personal satisfaction, push the drainage of wet spots in otherwise good fields.

J. R. HASWELL

# A. S. A. E. and Allied Activities

## Farm Structures Conference

AN INFORMAL conference of members of the American Society of Agricultural Engineers interested in farm structures was called by Deane G. Carter, chairman of the Farm Structures Division of the Society, and held in Chicago, March 22. The calling of this conference was prompted by a feeling expressed by a number of members that, to insure maximum and at the same time sound progress in farm structures, it is necessary to analyze in a careful and comprehensive manner the needs in this field and to develop a broad, constructive program for structures work in the Society, based on the best judgment and coordinated ideas of members of the Society most interested and most active in the farm structures field.

The conference just held in Chicago made substantial progress in this direction. The keynote of the conference is best expressed by the question, "Do we have a sound economic basis for farm structures design?" The conference was devoted to a discussion of problems of farm structures demanding attention and a presentation of ideas on what should constitute the future program of the Farm Structures Division of the Society with a view to coordinating the efforts of agricultural engineers engaged in farm structures work, so that the various problems might be attacked in a constructive, coordinated manner. The conference will be continued at the farm structures session to be held during the annual meeting of the Society at University Farm, St. Paul, Minnesota, June 22 to 25.

In order that some tangible results might be achieved as a result of the conference prior to the June meeting, those in attendance set up a program which they pledged themselves to complete by June. This program includes the following:

1. Preparation of a complete list of research projects on farm structures and related equipment now in progress in federal and state experiment stations
2. Preparation of a list of problems in farm structures and equipment requiring research. (This list will be confined to the contributions of those attending the conference but will be added to by suggestions from other members following the annual meeting of the Society.)
3. Preparation of a bibliography of farm structures which is essential in undertaking any program of research

The conference unanimously recommended that a meeting of the Farm Structures Division be held at Chicago during the week of the International Livestock Show next December, the dates specified being December 1 and 2.

## Meeting of the Pacific Coast Section

THE spring meeting of the Pacific Coast Section of the American Society of Agricultural Engineers will be held the first week in May at the Commonwealth Club, San Francisco. At this writing the exact date has not been set.

The morning session will feature the subject, "What Can Agriculture Afford to Pay for Irrigation." The principal speakers on this program include Dr. Elwood Mead, U. S. Commissioner of Reclamation; Frank Adams, professor of irrigation investigations, University of California; R. P. Teele, U. S. D. A. Bureau of Agricultural Economics, and P. A. Ewing, irrigation economist, Division of Agricultural Engineering, U.S.D.A. Bureau of Public Roads. The meeting will also be addressed by one or two persons who have had actual experience in developing irrigation projects. This subject is a very live topic throughout the West at the present time and a great deal of interest is being manifested by members on the Pacific Coast in this program.

The afternoon session will feature the subject "Some Conclusions From Studies of the Kinematics and Dynamics of the Wheel-Type Farm Tractor," by E. G. McKibben, junior agricultural engineer, University of California.

## College Division Advisory Committee Meets

THE Advisory Committee of the College Division of the American Society of Agricultural Engineers held its annual meeting at Washington, D. C., March 7 to 9, with full attendance. H. B. Walker, chairman, presided, having been appointed chairman by President O. W. Sjogren to complete the unexpired term of L. J. Fletcher.

A large part of the first day was devoted to a review of the actions taken at the 1926 meeting. This was an innovation introduced by Chairman Walker in line with his idea that more attention should be paid to actions taken at previous meetings of the Committee, as a means of promoting their effectiveness.

One of the matters that has been discussed at several meetings was that of aims and objectives. It was the general opinion that it was time to decide finally upon a suitable statement, and action accordingly was taken to bring this matter before the College Division session of the annual meeting of the Society at St. Paul in June for final disposition.

A committee was appointed consisting of Messrs. Walker, Nichols, and Musselman to study the geographic division of the Society on the basis of membership and interest, rather than on areas. Some objection was expressed to the twelve geographic subdivisions presented to the Committee last year.

In regard to commemorating the founding of the Society, action was taken to recommend to the Council of the Society that a bronze tablet be placed on the building, at the University of Wisconsin, where the Society was originally organized.

The matter of relations with the Society for the Promotion of Engineering Education was discussed at some length and the conclusion reached that it is essential that the importance of agricultural engineering in some manner be brought to the attention of that society.

The old subject of farm building plans again received attention, and recommendations were made that the list prepared by the federal division of Agricultural Engineering be continued and brought up-to-date. It was the general opinion that some means should be taken to effect an exchange of certain kinds of plans between the states.

The Committee considered at some length the matter of the qualifications of the agricultural engineer research worker in the pure sciences. It was held that the workers should at least be prepared to discuss the scientific phases of their problems with the appropriate specialists.

The importance of a center or clearing house from which information with regard to research in progress could be secured was emphasized. The matter will be put up to the federal department of agriculture. It was decided, with regard to the proposed bureau of agricultural engineering in the federal department, that activities should be continued and action was taken to request the Council of the Society to set up a committee to further this movement.

It was urged that department heads see that copies of AGRICULTURAL ENGINEERING are available in the libraries of their institutions.

The question of membership qualifications was considered with the result that the Council of the Society will be asked to give this matter attention.

In the matter of employment of graduate and undergraduate agricultural engineers by the implement industries, emphasis was laid upon the importance, on the part of the institutions, of placing only good men in the industries.

A classification of the members of the Society by geographic location and by grade was called for.

The chairman brought up the question, first brought forward by L. J. Fletcher, of a five-year program for the Advisory Committee. It was felt that a number of subjects lent themselves very well to such a long-time program.

One of the outstanding items of the meeting was the action

taken looking to the establishment of a national exhibit of agricultural equipment. It was arranged that this matter should be taken up at the annual meeting of the Society and a definite campaign laid out to accomplish this.

Some consideration was given to the advisability of changing the time of meeting of the Committee so as to coincide with that of the Association of Land-Grant Colleges, but no action was taken.

## Standardizing the Loan of Farm Machinery

THE problem of working out a uniform and equitable arrangement for the loan of farm equipment by manufacturers to the departments of agricultural engineering of the state colleges and universities has been prominently before those concerned for some time. The Advisory Committee of the College Division of the American Society of Agricultural Engineers at its meeting in Washington, D. C., March 1, 2, and 3, 1926, went on record as favoring standardized procedure in the loan of farm equipment, and at the request of the Committee, which met early in March of this year in Washington, we are presenting the resolution adopted by the Committee at its meeting last year, for the benefit of Journal readers connected with both manufacturing organizations and the state educational institutions. The resolution reads as follows:

"WHEREAS it has been recognized that the instruction in farm equipment offered by the departments of agricultural engineering in the state colleges and universities is of interest to the manufacturers of farm equipment, and

"WHEREAS the departments of agricultural engineering have in the past enjoyed the cooperation of the manufacturers and have been furnished equipment for display and demonstration, and

"WHEREAS uniform practice in carrying out such cooperation has been found to be desirable and instruction and research in farm equipment in the colleges and experiment stations will be greatly benefitted if this cooperation may be extended, therefore be it

"RESOLVED by the Advisory Committee of the College Division of American Society of Agricultural Engineers that the following principles should govern cooperation in furnishing of equipment:

1. When farm equipment is furnished for instructional and display purposes it shall be loaned to the departments of agricultural engineering subject to recall and frequent exchange. A signed receipt shall be given for the equipment and the institution receiving such loan shall be fully responsible for the safety and return of such equipment in good order. Such equipment shall not be used in field demonstrations unless permission is specifically granted by the manufacturer.
2. When farm equipment is used for regular operation on the college farm it shall be purchased by the college or university on such terms as may be granted by the manufacturer.
3. When equipment is to be used in experimental or research work by departments of agricultural engineering, which is of direct interest to the manufacturer, the terms on which the equipment is furnished shall be arranged in each instance, but it is recommended that such cooperation is based, in every instance, on a carefully outlined experimental project statement.

## Research Council Meets in Chicago

THE U.S.D.A. Advisory Council on Research in Mechanical Farm Equipment met in Chicago March 10 to formulate the future program of the survey, which will be under the immediate direction this year of H. B. Walker, professor of agricultural engineering at Kansas State Agricultural College. During his connection with the Department of Agriculture Prof. Walker will hold the title of "senior agricultural engineer."

Director Walker submitted a proposed outline of work that was used as the basis for the discussion of the 1927 program, which included the following main topics: Soil dynamics and tillage; weed control; crop production studies; harvesting studies; grain and forage processing; pest control machinery; fertilizer studies; new machines (or new applications); dairy equipment; water systems and pumps.

This program includes the encouragement of studies of a basic nature in soil tilth and dynamics. The production problems will include not only the essentials in machines but methods and costs as well. Two basic crops, corn and cotton, are included. The harvesting program includes chiefly combine studies, including also studies in corn and cotton harvesting. The grain and forage processing work is already well organized in connection with C.R.E.A. studies.

In connection with pest control machinery, the C.R.E.A. studies already include stationary sprayers, and in addition the corn borer control work is now well under way. The fertilizer studies will be a continuation of work under way as well as a correlation of any new work which may be undertaken. The new machine studies will include those of importance which may be developed in connection with the research program. The attitude of the Council is that the utilization of existing machines is more important as a general problem than the development of new machines. Dairy equipment with the exception of mechanical milkers, and water systems are well covered at present in C.R.E.A. studies.

As a general policy, all projects not specifically mentioned in the outline submitted by Director Walker, but which are now under way, will be encouraged and enlarged if feasible and correlated with the national program of research.

A summary of projects and problems now under way and including also those suggested was submitted by Director Walker for the information of the Advisory Council.

The advisory Council at its meeting made excellent progress in formulating a definite program for developing and coordinating research studies. Whereas the work of the past year on this research survey has been largely devoted to a study of the status of research in mechanical farm equipment in this country and an analysis of the problems requiring research, the program of the future will be to encourage the continuation of work now in progress, the proper correlation of related projects conducted by the various research agencies, and the institution of research studies of immediate importance to the agricultural and allied industries.

The far-reaching significance of this research survey is probably not generally appreciated at the present time. Since the survey was instituted the progress made has been most gratifying and the ultimate results to the industry of agriculture in this country are certain to be of tremendous importance.

## To Study Cotton Production Costs

A RESEARCH project is being started at the North Carolina Agricultural Experiment Station to study cotton production costs. The project outlined has for its object the comparison in costs of some of the typical methods used in South Carolina of applying labor and power with some of the advanced methods that are now being used in the newer cotton areas of the Southwest. The tests will be carried out on typical Piedmont conditions, the land having considerable slope and frequent terraces. It is not expected that definite or conclusive results are to be had from a one year study, but it is expected that the studies will reveal the possibilities of improving present practices in applying labor and power. The project is prompted by the conclusion that if cotton is to continue as the main source of income on South Carolina farms, the cost of producing it will have to be reduced.

The project is a cooperative one between the farms and agricultural engineering divisions and will be financed by Purnell and supplementary funds. The leaders of the project are C. S. Patrick and J. T. McAllister (Mem. A.S.A.E.) agricultural engineer.

## Standard Speeds for Machinery

STANDARDIZATION on a national scale of the speeds of machinery is proposed by the National Electrical Manufacturers Association in a request to the American Engineering Standards Committee to take the matter up with the purpose of simplifying and clarifying the existing situation which is stated to constitute a serious burden on industry through the resulting waste and confusion.

In making the request the Association states: "Under present conditions the curve of the speeds of driven machinery is practically a random distribution without any logical ordering of the values used. As a result of this, the sizes of pulleys, gears, sprockets, etc., which manufacturers have to produce, and which manufacturers, jobbers, dealers and users must keep in stock have been multiplied almost endlessly. While the need for simplification of driving and driven connections has been apparent for years, particularly to producers of electric motors, steam engines, etc., nothing

has been accomplished, because without coordination and standardization of the speeds of driven and driving machinery considered together, no satisfactory solution can be obtained."

It is the view of the electrical manufacturers that the proposed standardization which should result in a relatively small number of coordinated speeds for the almost innumerable kinds of machinery, would afford an easy approach to the problem of simplification and standardization of pulleys, gears, sprockets, etc., and would permit much greater flexibility in the selection and use of both power units and driven machinery, greatly promoting interchangeability of such units, and providing economies for innumerable industries dependent upon such equipment.

As the first step, the American Engineering Standards Committee will convene a general conference of the principal trade associations, technical societies, and other groups interested in this subject.

## A New Idea in Education

A RECENT visitor at the headquarters office of the American Society of Agricultural Engineers was Charles Kuntz, a member of the Society, who is developing a very interesting plan for coordinating the processes of agricultural education and production.

Mr. Kuntz is one of the incorporators of the International Polytechnical University incorporated under the laws of California. Associated with Mr. Kuntz are several others, all of whom are American citizens but some of whom were born in Russia.

This organization has recently completed arrangements with the Soviet government of Russia for establishing an agricultural educational institution, to be known as the "Agricultural Institute," in the Province of Ukraine on the banks of the Dnieper River. While the enterprise is technically under the jurisdiction of the department of education of the Soviet government, Mr. Kuntz and his associates will be given a free hand in developing the educational system which they are sponsoring. A grant of 8000 acres of land has been obtained from the government and Mr. Kuntz has recently returned to this country to arrange for the equipment and personnel needed. The Institute will be opened October 1 with about one hundred students.

Agriculture in Russia, including production as well as marketing, is on a strictly cooperative basis. The Agricultural Institute has been organized also as a strictly cooperative project. The students attending this institution will do all the work on the Institute farm, and profits realized from the products produced and marketed will be used to support the enterprise. The aim is that the Institute shall eventually be self-supporting.

Students will divide their time between work on the farm and the theoretical study of agriculture. Mr. Kuntz states that in developing the Institute the subject of agricultural engineering will be particularly stressed as, in his opinion, the mechanics of production is the principal determining factor in the success of any agricultural enterprise.

Those who are particularly interested in this project may obtain further details by addressing Charles Kuntz, 180 Broadway. New York, N. Y.

## Blacksmithing on the Wane

CHANGING conditions brought about by the general use of the automobile and the telephone are reflected in a decreased demand by students of the agricultural department of the University of Minnesota for instruction in blacksmithing. Twenty years ago farmers often had urgent need, particularly in rush seasons, for the home forge. Today the automobile and the telephone have put them in such close contact with the "village blacksmith" that the home blacksmith shop no longer figures in the time element as it once did. As a matter of fact, in many sections of the country the "village blacksmith" is practically extinct.

Equipment and instruction to fit the new conditions are being provided by Prof. William Boss and his staff of agricultural engineers at University Farm. Many of the forges in the shops there have been sold and the old course of three months of blacksmithing and three months of steel work has been compressed into three months, two of which are given to instruction in cold metal work, in charge of J. G. Dent.

While a break in most modern machinery is no longer a forging job, the farm shop is still needed for doing various kinds of cold metal work, including the use of taps and dies, drilling, pipe fitting, soldering, etc. Training which will give the student ability and skill in operating mechanical equipment under the new conditions is the purpose behind the new course. Forgings will not be ignored, but will not be featured as before.

## Personals of A.S.A.E. Members

**E. V. Collins,** assistant agricultural engineer, Iowa Agricultural Experiment Station, is joint author with A. B. Caine of Bulletin No. 240, entitled "Testing Draft Horses," just issued by the Iowa Experiment Station.

**R. M. Gray** is one of five incorporators who recently organized the Table Mountain Properties, Inc. This $600,000 company was organized to increase the irrigation and dairy and livestock operations already under control of these men. The Table Mountain Ranch near Oroville in northern California will be the center of the dairy operations of the company. Alfalfa will be the principal crop; it has yielded in the past seasons, on land under irrigation on this ranch, higher than eight tons of hay per acre.

**W. A. Harper** has been appointed by the Caterpillar Tractor Company, Peoria, Illinois, as an assistant to **L. J. Fletcher,** supervisor of agricultural sales. While attending Ohio State University Mr. Harper was president of the student branch of A.S.A.E., and was the official delegate of the Ohio Student Branch to the annual meeting of the Society in 1925. After graduation he became affiliated with Hart-Parr Company, in charge of sales promotional work, which position be held until taking up his new duties with the Caterpillar Tractor Company, April 1.

**F. N. G. Kranich** recently became associated with the manufacturing organization of the International Harvester Company and will devote special attention to the thresher and harvester-thresher lines.

**S. H. McCrory,** chief, division of agricultural engineering, U.S.D.A. Bureau of Public Roads; Anson Marston, dean of engineering, Iowa State College, and F. C. Hills, of Jacksonville, Florida, are serving as members of an engineering commission that is now making a study of the Florida Everglades for the Internal Improvement Board of the State of Florida.

**James C. Marr,** associate irrigation engineer, division of agricultural engineering, U.S.D.A. Bureau of Public Roads, is author of Department Bulletin No. 1456, entitled "Drainage by Means of Pumping from Wells in Salt River Valley, Arizona," just issued by the U. S. Department of Agriculture.

**Dalton G. Miller,** drainage engineer, U. S. Department of Agriculture, is author of a bulletin, entitled "Review of Work of Cooperative Drain Tile Laboratory With Recommendations," just published under the direction of E. V. Willard, commissioner, Department of Drainage and Waters, State of Minnesota. This laboratory is conducted by the department of agriculture of the University of Minnesota, the department of drainage and waters of the State of Minnesota, and the U. S. Department of Agriculture cooperating.

**B. J. Owen,** director, Institute of Agricultural Engineering, Oxford University, England, is joint author with L. F. Manes and J. L. Dougan of a contribution on the subject of discoveries in the treatment of sugar beets for the production of sugar, appearing in the February 1927 issue of the Journal of the Ministry of Agriculture, London. The article gives an account of the improvements which have resulted from

recent researches into the dessication method of producing sugar from sugar beets.

**L. C. Prickett,** formerly rural applications engineer for the General Electric Company, has been appointed assistant director of the national Committee on the Relation of Electricity to Agriculture, of which Dr. E. A. White is director. Mr. Prickett is filling the place left vacant by the recent resignation of Frank D. Paine. He will take up his new duties immediately.

**C. O. Reed,** professor of agricultural engineering, Ohio State University, is in charge of the engineering division of the U.S.D.A. ten-million-dollar corn borer clean-up campaign that started March 14.

## New A.S.A.E. Members

**Rudolph J. Altgelt,** implement designer, Oliver Chilled Plow Works, South Bend, Indiana.

**R. Dudley Barden,** extension specialist, Ohio State University, Columbus, Ohio.

**Sherman W. Cady,** designing, improving and testing farm machinery, International Harvester Co., Chicago, Illinois.

**Arvy Carnes,** assistant professor of agricultural engineering Alabama Polytechnic Institute, Auburn, Alabama.

**D. Howard Doane,** agricultural engineer, Doane Agricultural Service, St. Louis, Missouri.

**William Durbrow,** managing and directing irrigation and reclamation works, Glenn-Colusa Irrigation District, Willows, California.

**Harold E. Engstrom,** civil engineer, Albert Lea Farms Co., Hollandale, Minnesota.

**J. Raymond Golden,** northwestern sales manager, Matthews Engineering Co., Sandusky, Ohio.

**Alpheus M. Goodman,** extension professor of rural engineering, N. Y. State College of Agriculture, Ithaca, N. Y.

**John B. Gordon,** agricultural field engineer, Portland Cement Association, Chicago, Illinois.

**Greta Gray,** professor of home economics, University of Nebraska, Lincoln, Nebraska.

**G. D. Groce,** service manager, The Cleveland Tractor Co., Cleveland, Ohio.

**Joseph W. Gross,** civil engineer, Sacramento, California.

**Ivan Ivanoff,** tractor student, Ford Motor Co., Detroit, Michigan.

**A. E. W. Johnson,** superintendent of experiments, International Harvester Co., Chicago, Illinois.

**Leon B. Lent,** engineer, Common Brick Manufacturers' Association of America, Cleveland, Ohio.

**T. A. H. Miller,** associate agricultural engineer, U. S. Department of Agriculture, Branchville, Maryland.

**John Novikoff,** tractor mechanic, Ford Motor Co., Fordson, Michigan.

**John W. Purcell,** assistant engineer, Hydro-Electric Power Commission of Ontario, Toronto, Ontario.

**Charles C. Ross,** field engineer, King Ventilating Co., Owatonna, Minnesota.

**William J. Schlick,** drainage engineer, Iowa State College, Ames, Iowa.

**Clement L. White,** managing editor, The Pennsylvania Farmer, Lawrence Publishing Co., Philadelphia, Pennsylvania.

**Augustus F. Whitfield,** president, Clover Fork Coal Company, Kitts, Kentucky.

**Horace J. Young,** agricultural field engineer, Portland Cement Association, Lincoln, Nebraska.

### Transfer of Grade

**Walter T. Ackerman,** state leader of electrical project, University of New Hampshire, Durham, N. H.

**Wilbur M. Hurst,** junior agricultural engineer, U.S.D.A. Bureau of Public Roads, Washington, D. C.

**W. C. Krueger,** University of Wisconsin, Madison, Wisconsin.

**L. C. LeBron,** extension agricultural engineer, Alabama Polytechnic Institute, Auburn, Alabama.

**J. Dewey Long,** junior agricultural engineer, University of California, Davis, California.

**Walter A. Rowlands,** assistant professor of agricultural engineering, University of Wisconsin, Madison, Wisconsin.

**James A. Waller, Jr.,** assistant professor of agricultural engineering, Virginia Polytechnic Institute, Blacksburg, Virginia.

**William J. Welker,** instructor in agricultural engineering, Claresholm, Alberta, Canada.

## Applicants for Membership

The following is a list of applicants for membership in the American Society of Agricultural Engineers received since the publication of the March issue of AGRICULTURAL ENGINEERING. Members of the Society are urged to send information relative to applicants for consideration of the Council prior to election.

**Joseph L. Baker,** salesman and demonstrator, International Harvester Co., Peoria, Illinois.

**Walter K. Clore,** manager, Compania Central Altagracia, Ingenio Oriente, Oriente, Cuba.

**H. Warren Denison,** assistant ventilation engineer, The Louden Machinery Co., Fairfield, Iowa.

**Frank W. Flack,** Iowa Railway &Light Corporation, Cedar Rapids, Iowa.

**F. H. Higgins,** research department, National Association of Farm Equipment Manufacturers, Chicago, Illinois.

**Arthur C. Jenvey,** general sales manager, Western Harvester Co., Stockton, California.

**Frederic A. Lyman,** research assistant, National Association of Farm Equipment Manufacturers, Chicago, Illinois.

**Francis G. North,** lecturer, MacDonald College, Quebec, Canada.

**Gladstone Reed,** consulting farm manager, United Bank & Trust Co., Fresno, California.

**Bertram D. Scott,** sales manager, Louden Machinery Co., Fairfield, Iowa.

**H. C. Wallace,** sales manager, Link Mfg. Co., Kansas City, Missouri.

**Frank G. Wells,** manager, Olson Mfg. Co., Albert Lea, Minnesota.

### Transfer of Grade

**Raymond P. Frey,** instructor, University of Saskatchewan, Saskatoon, Saskatchewan, Canada. (Student to Junior Member).

## Employment Bulletin

### Men Available

AGRICULTURAL ENGINEER available. Seventeen years experience in the designing and manufacture of farm tractors, motor trucks, harvesting machines, and earth-working tools. Sales experience in United States, Canada, England, France, and Italy. Write for interview. MA-132.

AGRICULTURAL ENGINEER, graduate of University of Illinois, nine years teaching experience as assistant professor in one of the largest universities of the central west. Eleven years manufacturing experience with one of the large tractor and farm implement builders. Experienced in production, design, and management. Desires position preferably as extension agricultural engineer or experimental or production manager work. MA-133.

AGRICULTURAL ENGINEER, 1924 graduate of University of Wisconsin, desires permanent connection. Past experience includes tree surgery and tractor motor inspection. Prefers duty on private estate or investigational work. Edwin A. Bier, 515 N. Church St., Rockford, Ill.

AGRICULTURAL ENGINEER wants responsible position in Canada in experimental or engineering work. Experienced wood patternmaker and draftsman. Eight years with present employers as patternmaker and later in charge of experimental work. Age 35 years and married. Wants position with better opportunity for growth. MA-139.

### Positions Open

SALES MANAGER OR ASSISTANT SALES MANAGER WANTED. Agricultural engineer with sales experience preferred. Ample opportunity for advancement. Business now doing $500,000 volume on a varied line of farm equipment items in ten central western states. PO-122.

AGRICULTURAL ENGINEER, recent graduate, wanted by farm equipment manufacturer to take over work of demonstrating and introducing new tractor guide. Must be able to handle tractors in the field, make some designs, take orders, and eventually look after advertising and sales. PO-123.

SUPERINTENDENT wanted for a plow and tillage implement plant in Illinois. A competent and experienced man who has had some technical training is required. PO-124.

DESIGNER in engineering department of a plow and tillage implement plant in Illinois wanted. Man with technical education and two or three years experience required. PO-125

ADVERTISING MAN wanted with experience in the farm equipment business. Must have executive ability. Someone with motor truck experience preferred. PO-126.